THE ORIGINS OF ASTRONOMY, THE CALENDAR AND TIME

ऐतिह्यासिक खगोलविध्य
ज्योतिःशास्त्रं
पंचांगम
कलविधान शास्त्र

Kosla Vepa PhD

a critique of the conventional western narrative of the history of astronomy and associated sciences in Indic antiquity

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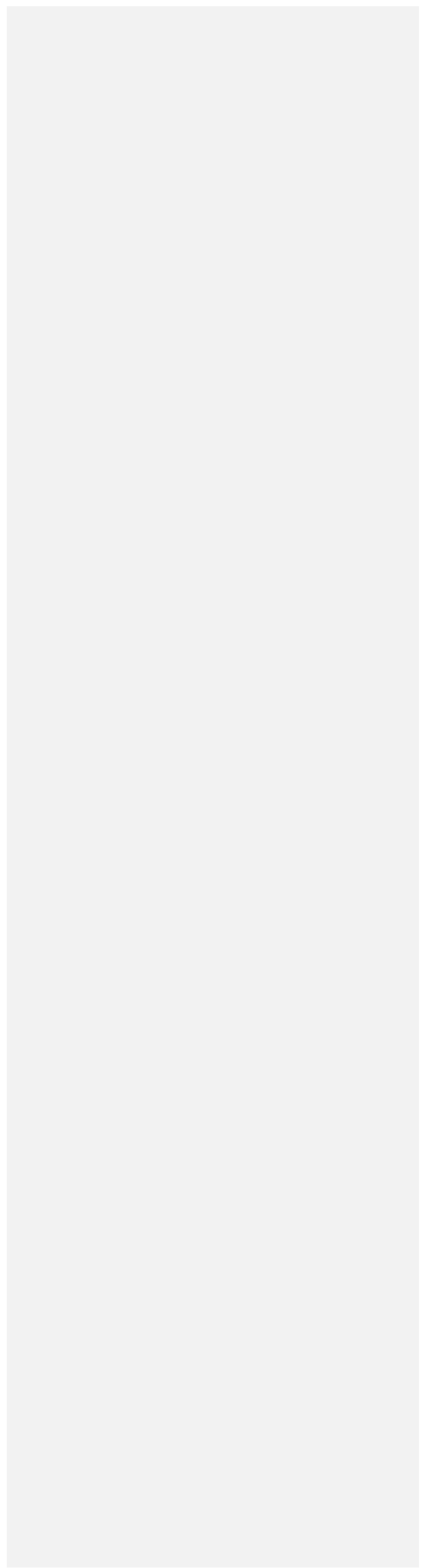
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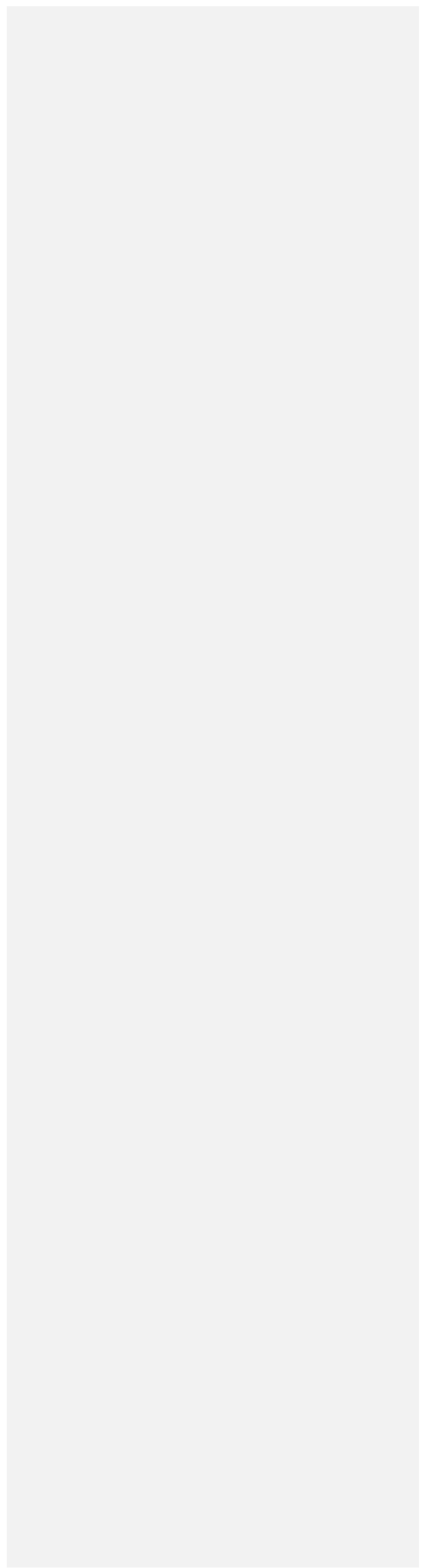
THIS BOOK IS DEDICATED TO THE MEMORY OF
MY PARENTS

VEPA ANNAPURNA &
VEPA LAKSHMI NARASIMHA ROW

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FOREWORD

It is with a sense of awe that I am writing these few words, which are totally inadequate to explain my true feelings about this book, “The origins of Astronomy, the Calendar and Time” By Dr. Kosla Vepa and published by McGraw-Hill Open Publishing. This is a book about relating the true story of Indic contributions to astronomy in particular. At the outset the author makes it clear that the Indic contributions to science in general and astronomy and mathematics in particular have been ignored and even denigrated by the western historians of science with a bias not shown towards the contributions of any other culture. The author meticulously traces the origins of the history of science and shows clearly how the early historians properly acknowledged Indic contributions and gave due credit, but latter day western historians from the 18th century onwards systematically followed a path which denied any credit to Indic contributions. Moreover the accounts of these later scholars are colored by the influence of the so-called Aryan Invasion Theory. Although this theory has now been thoroughly discredited, its influence has been so pervasive that it is difficult to find any work which can give an unbiased view of the history of Indic contributions to science in general and astronomy in particular. The book by Dr. Kosla Vepa fills this lacuna.

There have been a few excellent books on the history of astronomy such as those of Sen and Subbarayappa, just to mention, on the Calendar the work of Meghnad Saha, and on Time, the works of C K Raju. However, this book treats the history of all the three topics in combination and hence derives its encyclopedic nature. Dr. Vepa, while bringing out clearly the Indic contributions, he also emphasizes that scientific spirit of enquiry has no geographical or nationalistic boundaries and that its universal nature must be appreciated.

A good size book, of over 600 pages, it has twelve chapters and various appendices and endnotes. Appendices alone run to over 200 pages. All in all it is almost an encyclopedia. It is an interesting book to read with all kinds of tidbits of information and historical facts for the casual reader, but includes enough mathematical treatment for the serious reader. It forms an excellent reference for graduate work with its extensive appendices. It is a must for the desk of anybody interested in the history of Astronomy and the Calendar.

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PREFACE

The writing of this book has been a highly satisfying experience for me. In so doing, I have learned a lot about the Ancient Indic and his way of life. And yet we are still in the infancy of trying to decipher the Indic past before I do so I wish to share with the reader how my interest gravitated to this subject.

It was during the late 60's and early 70's that I went back to graduate school after a 5-year stint in industry in India, West Germany, and Canada. My employment at the time I went back to School was not in jeopardy and I had completed a highly productive period where I had developed the first finite element computer code to evaluate the structural integrity of rotors used in aero engines. This was in 1967 when such codes were not available commercially and in fact the theory behind the method was only imperfectly understood by a small group of practitioners. The subject fell under the general rubric of Engineering Mechanics. The reason I went back to school was that I felt I had to augment my knowledge in the field of mechanics.

During my Graduate Studies at Waterloo in Canada I came in contact with leading practitioners in the field of Engineering Mechanics. I developed an interest in the history of mechanics starting from Greece to Leonhard Euler and the development of Variational methods that would utilize the Principles of Conservation. In fact I give a brief account of the history of mechanics, especially the Global principles that are used to determine the equations, in my thesis. I read a lot about the history of mechanics, and one book that made a deep impression on me was "Essays in the History of Rational Mechanics "by Clifford Truesdell. From that point onwards I have maintained an abiding interest in the history of Mechanics and Mathematics[1], since many of the practitioners in the field of mechanics were also first rate Mathematicians, a state of affairs that lasted virtually till the time of Hénri Poincaré, arguably the last of the great mathematical savants of Europe, who was knowledgeable in a broad range of topics in the field of Mathematics.

As I was researching the history of mathematics, it dawned on me that a lot of the numerical techniques used in Engineering had their antecedents in the work of ancient Indic mathematicians. Until then I was focusing on Greek mathematics. But apart from the work of pseudo Euclid (who used little or no Algebra) and the work on conic sections by Apollonius, I did not find the Greek effort particularly rich in algorithms. It took many years for me to realize that most of the Algebra, Analytical geometry and Trigonometry, we deal with in High school and even at an undergraduate level, did not have its roots in the Occident. My desire to learn more about the Indic contribution continued to be hampered by lack of adequate texts on history of ancient Mathematics in the English language. While the situation was slightly better in French and German, the trail was very cold by the time you went back beyond 1400 CE and could not pick up any of the threads in the work of the Greeks. I came to the realization that there was very little extant of the Greek work in mathematics and this is even truer in the case of Astronomy. No European text could explain in a satisfactory manner why there was no progress in the sciences in Europe between the beginning of the Common Era and 1400 CE other than saying that the Church played a big part in structuring the content and extent of education. What is particularly galling is that the Occidental admits that all Greek work was lost to Europe, but he credits the Indic with getting their hands on the Greek work, even though these works were presumably lost at a very early time. It seems to us an even more likely scenario was that whatever Greek texts existed at that time became rapidly obsolete and were no longer reproduced because there was no longer any need for them.

[1] *My interest in the history of Mathematics extended eventually to other areas of history including a broad range*

The stonewalling of the Indic contribution has strong parallels in the effort to emasculate the Indic tradition, and it is only after I read extensively in the Indology literature, did I realize that the whole pattern of denigration of the Indic past was a concerted effort to reduce the Indic civilization, at best to an 'also ran' category.

The main reason for writing this book is that the real story of the Indic contribution to Astronomy has yet to be told. Few books give a coherent account of the Indic odyssey as it unfolds from the mists of antiquity to the pioneering work of Astrophysicist Subramanyan Chandrasekhar on the nature of the universe. If they do mention it at all, it is merely to say that they borrowed everything from Western historians of Mathematics (e.g. Toomer, Van der Waerden, Otto Neugebauer, or David Pingree) as their authoritative source. Rarely will they mention a Primary source in Sanskrit, because they are not familiar with the literature in Sanskrit and they do not trust the Indians to tell the true story. They prefer to get the story from an Occidental who may not have read a single book in its Sanskrit original rather than get it from Indian sources[2]. The net result is a book filled with clichés where the content is already degraded from multiple levels of interpretation and inadvertent filtering of the original source.

Typical of recent books is one by Glen Van Brummelen[3] on the Mathematics of the Heavens and the Earth. This book is better than most since it mentions India and devotes a full chapter to India. But it makes the obligatory bow to the notion that India is a secondary source of developments when he titles the very first section in this chapter "Transmission from Babylon and Greece". There is absolutely no evidence given of this vaunted transmission and yet we are asked to accept this statement unquestioningly. He then goes on to say that much of the origin is controversial and is marred by national pride. This is indeed a strange remark to make. It is accepted that the English should have pride in the achievements of Sir Isaac Newton but this would hardly be regarded as an issue in evaluating the work of Newton. Then he goes on to say, "There seems little doubt that the spark for Trigonometry came from importing of some Pre-Ptolemaic version of Greek mathematical astronomy". The casual manner with which he makes this categorical assertion, and which denies the Indic civilization the originality of its contribution in Trigonometry is stunning in its certitude and hubris. He then goes on to cite Pingree as a starting point. This reminds me of an Indian Proverb that translates "In the land of the blind, the one eyed man is King".

There is one final point to be made. Nowhere does he mention that there is an equal likelihood (and in my opinion a far greater one) that it was the Greeks who learnt Mathematics and Geometry from the Indics. I amplify on the possibilities of this in the chapter on transmissions. The refusal to entertain such a possibility is a telling commentary on the lack of objectivity and I would go so far as to say that there is not even an attempt at such objectivity.

I regard this book to be primarily a pedagogical text, despite the fact that I have glossed over important derivations. I believe like the Bhāṣyakāras of yore in proper understanding of what we already know. The choice of material to include in the book always presents a dilemma. The scope of Ancient Indic Mathematics and Astronomy is so large that it would need several volumes to provide an exhaustive encyclopedic coverage. The alarming increase in the size of the book forced me to make difficult choices. However, we are planning a sequel to this text, which will contain many of the missing topics as well as amplify on the main principles of the astronomy of the solar system as practiced by the ancient

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[2] *I am reminded of the Parable of the Lost Coin. This is the story of the man looking for a lost coin in a well lighted area, when he knows he has lost it in a darker area of the garden. When asked why he was looking for it where he certainly couldn't find it, the man replied "But it is better lighted here and I can see what i am looking for". Clearly the Parable of the lost coin is entirely apropos here*

[3] *Glen van Brummelen, 2009, Mathematics of the Heavens and the Earth, Princeton University Press, Princeton, NJ.*

The time line for this study is a rather large one dating from the compositions of the Veda (7000 BCE), through the Sūtra period, the Pre-Siddhāntic period, the Jaina contributions up to the Siddhāntic era, and finally ending with the Keplerian Newtonian formulations (17th century CE).I would like to think that the book would be of interest to a wide range of people. It should be of interest to the layman, as it provides a lot of reference material on History and the Calendar. It could serve as a textbook in a course on the history of Astronomy. It would serve as an excellent introduction for amateur astronomers and last but not least it could serve as a reference for graduate level research.
This is primarily a book on the origins of Astronomy as the title aptly suggests and in writing it I have been to some of the places, I have listed in Appendices I and K such as the British Library, London, École Française d'Extrême-Orient in Paris, and in Pondicherry,India the School of African and Oriental Studies, London, the Columbia University Library in New York, The Travancore University Library in Thiruvananthapuram, The Adyar Library in Chennai, the Bhandarkar Oriental Research institute in Pūṇē, and I have had access to the excellent collection at University of California at Berkeley. My quest was in search of the latest vulgate text of the primary sources. I have built up a sizable library of my own in Sanskrit, English, Hindi, German and French in the areas of History of Mathematics and Astronomy. I have written the book from the point of view of an informed journalist and a consumer of History with a passion for deciphering the past.

THE CHALLENGE AND THE OPPORTUNITY

The Indic civilization is under attack today both from within and without. So thorough has been the effort at devaluing this civilization, that large sections of the Indic populace do not feel a sense of ownership in the civilization and do not identify their evolution as being congruent with the continued viability of the civilization. The English language has made deep inroads into the subcontinent and its usage in India is irreversible. As envisaged by Thomas Babington Macaulay, the English educated Indic looks at Indic traditions from the viewpoint of an occidental. As we discuss the situation in Astronomy and the measurement of time in this book, it is clear that the reasons are manifold, but a growing ignorance of the Indic past is definitely high on the short list of the main causes. But with every challenge there comes an opportunity. The pervasiveness of English in higher Indian education presents an opportunity. The window into the achievements of the Occident that the English language has given us, provides us with a second wind, another chance to do comparative studies of the ancient Indic episteme vis a vis that of Greece and Babylon and show that the eternal verities and the Epistemes that our ancestors have bequeathed to the modern Indic, are not just a flash in the pan, but part of an enduring tradition. In order to overcome this challenge, there are difficult tasks to perform.

- The first is to realize that a synthesis of Epistemes is possible, and an ongoing synthesis is indeed necessary for survival.
- The second is to define and articulate the goals, objectives, and form of the synthesis
- The third is to successfully execute the synthesis.

I propose that a major part of what I define as the Synthesis involves the mastery of the various streams of the Global episteme. The conventional wisdom in the Occident is that the Greek Episteme is regarded as pre-eminent. The mastery of the different Epistemes is not so easy, and would involve the learning of multiple languages (classical) such as Latin and Greek in addition to Sanskrit. I maintain that the Indic is in a unique position to do so, because of his recent proficiency in English, as long as he does not abandon his legacy in Saṃskṛta.

This would allow Indians to make a case that the vaunted prowess of the Ancient Greek Epistemes is in fact a chimera and occurs centuries after their incidence in Indian manuscripts and even after the lapse of considerable time there is lack of epistemic continuity in the West. As we assert in the book, and there are several such cases described in the work by CK Raju, such a lack of epistemic continuity heralds a period where no further progress takes place, which is exactly what happened in Europe after Ptolemy. Could it be that the reason why we do not find a plethora of Ancient Greek texts in the computational sciences, prior to the beginning of the common era, invoking Ockham's Razor, is the simple fact that they were superseded by better ones and fell into disuse because they were outdated and inaccurate.

Once the linguistic mastery is achieved, one can focus on the synthesis of the 2 or more approaches. Such an effort would facilitate the synthesis of various Epistemes and Technologies such as Ayurveda and the Biological sciences. This is a task that courageous and inquisitive Occidentals such as Jean Filliozat had begun but it is imperative that the Indic take the lead in this, so that he can define the direction and the metrics of such a synthesis.

THE OBSESSION OF THE WEST WITH REDUCING THE ANTIQUITY OF INDIA BY ANY MEANS AVAILABLE

Part of the reason I wrote this book is to influence all my readers, regardless of their ethnicity, ideology, or geography to adopt a more global perspective on matters relating to History and philosophy of the sciences. Under such a perspective, few would feel compelled to defend or attack a viewpoint if the extent of the antiquity was the sole issue at stake. But talking to the West in such conciliatory terms is inimical to any progress because most in the west couldn't care less about the antiquity of India, and those who do like Witzel have no intention of granting to the Indian the dignity of writing his own history.

The opposition to the antiquity of Indic literature is institutionalized to such a high degree in the west and is so well entrenched in the mind of the occidental that it is impossible today to have a rational conversation with an occidental on this topic. Most are not aware that their opposition to such a notion of high antiquity for India is not based on any evidentiary hypothesis, but is based purely on speculation and conjecture. I have tried to explain to the Indics that the current chronology of India as it is peddled in the school text books has no scientific basis behind it, other than the broken fragments of a traveler to India who did not have a great reputation to begin with in historiography, and even if we believed what he wrote, he does not say that he came to the court of Chandragupta Maurya. So, we asked ourselves what could be the possible reasons for this and we came up with the following.

1. Envy seems to be the main reason for people like Michael Witzel, who keeps harping on the antiquity frenzy of the new breed of historians, that he constantly attacks, forgetting that it always has been the Occidental who has raised the issue of Indic antiquity to such a high degree, that it almost appears to be the only issue that is non-negotiable. There is the added indignity, that what was a conquered nation should aspire to such lofty ambitions as having an intellectual tradition.

2. While the west never publicly endorses the uses of antiquity as a factor in the way it looks at other countries, it is clear by any analysis that those nations which have an uninterrupted continuity in their episteme and in other aspects of their culture fare better than those who don't in the way they are perceived by the rest of the world. Britain often went to extraordinary lengths to maintain continuity of their royalty, as in the case of George I, who did not speak a

word of English and it was the common talk in England that the British royal family was more German than British during most of the Eighteenth century That is why the Briitsh royals changed their name to Windsor from Saxe Coburg Gotha, which was part of the title of the unfortunate gentleman (Prince Albert) whose only official duties were to act as a consort for Queen Victoria. While the west jealously guards its traditions and its history in myriad ways, it will not grant the Indic the search for a cohesive view of Indic history and immediately starts whining about Indian nationalism inherent in such a posture.

3. My message to fellow Indics is that those of you who believe that India Is not a land of high antiquity and agree with the occidental in the current chronology of India, explain their reasons as to why they adopt such a posture, and in doing so come up with some original research rather than peddling the colonial paradigm which is totally devoid of any consistency, is massively at variance with the facts and has been arrived at in such a shockingly shabby manner.

4. The discovery that Sanskrit belongs to family of Indo-European languages, has been a major catastrophe for India. Were it not for this seemingly innocuous fact, the Indic would not have to put up with a lot of insecure individuals masquerading as indologists, who go into paroxysms of rage and make no attempt to hide the fact that their immense ego would never recover from the blow that Sanskrit is undoubtedly the most ancient language to be codified with a grammar in the known galaxy.

But the yearning for a competitive antiquity is not restricted to those of a particular ethnicity. It appears to be a predominant factor when a more aggressive and authoritarian civilization subjugates a people with a more advanced episteme. Time and again, this pattern of behavior has been the norm, where the aggressor has adopted the Epistemes of the subjugated people, after devoting a massive effort to absorb the knowledge, and once he is fairly confident that he has been successful in this endeavor, he will turn around and assert precisely the opposite, that in fact it is the subjugated civilization that has borrowed the episteme and the resulting knowledge.

Antiquity affects many factors that have a bearing on the sense of uniqueness that a people have of their own identity and a sense that continuity and longevity of a civilization bestows a modicum of a sense of wellbeing. A loss of epistemic continuity that is now being experienced in the Indian subcontinent has long-term consequences for the manner in which the Indians will look upon themselves. Civilization is a fragile artifact, if I may paraphrase Will Durant, the great historian who compiled the monumental Story of Civilization over a thirty-year period, and it does not take much to obliterate a civilization. All it takes is an utterly ruthless individual who by the force of his personality, ideas and incredible energy, can compel a sufficiently large populace to do his bidding and you may rest assured that such an individual will rise again. So how will the Indics handle such a situation in the future? Well for one thing, defeat under such circumstances is not an option and surely, the Indics will not get a third chance, when the patient was in comatose condition after the last 2 rounds. A decay of a civilization can also occur through sheer apathy and ignorance, when large sections of the populace remain happily oblivious of the past in a massive exhibition of epistemic amnesia. This is all the more sad when it occurs as a consequence of public policy adopted by the democratic representatives of an elected government and legislature.

This book is not about the glories of a bygone era, where one bemoans the ephemeral nature of an enlightened past. It is a recounting of the irreversible nature of the changes that take place when a civilization is subjugated, its traditions are ridiculed, its history is rewritten, its language is driven into oblivion, and any attempt to combat this assault albeit in a non-violent and scholarly manner marks the individual as fundamentalist. I am particularly amused that otherwise intelligent people have begun to

use the epithet of choice, the veritable nom de plume of being a Hindutvawadi. The calendar, astronomy, and the story of time combine to make a fascinating chapter in the story of the Homo sapiens, and it is the larger Civilizational canvas that I hope the reader will focus on.

What do I take away from the writing of this book? It is my faith in the universality of the human spirit. If there is one thing above all that I treasure from this experience is that the love of science and mathematics does not recognize man made geographies, boundaries, ethnic classifications, language, social strata, or economics. It is for this reason I find that the current Eurocentric emphasis which persists among authors even to this day and which resulted from the theft of vast portions of our intellectual heritage, to be an anathema and to be of a particularly egregious nature with which I have little sympathy and have no tolerance whatsoever.

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Suguna, my wife and partner in all our terrestrial travels and experiences during the last 5 decades, has built up a large library of books on Indian and Western Art, History. While the content of most of these books especially with regard to Indian History leaves much to be desired, the resulting intersection of interests has been beneficial in clarifying what is delinquent in the Occidental version of the story. She never ceases to amaze me with her boundless energy and zest for life I have been able to bounce ideas off her, and for that I am grateful. My children Sanjay and Kalpana have always been a source of immense support.

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I was pleased that Prof Alok Kumar after my success in tracking him down, had expressed his preliminary approval of the book and had promised to read the entire book during the summer months. If the reader will recall that it was his translation of the Saad Al Andalusi work (Tabaquat ul Imam) that had set me of on this quest to do a complete and thorough forensic investigation, the result of which is this book.

PROLOGUE
THE PARABLE OF THE LOST COIN

IS THE CALENDAR A SIGNIFICANT OBJECT OF STUDY AND HOW SO?

Anno Domini Nostri Iesu (Jesu) Christi ("In the Year of the Lord Jesus Christ") circa 1280 in a little village called Cambridge north west of London, a group of workmen began constructing structures to house Peterhouse, one of the first colleges constituting what would become in time one of the great learning centers of Europe and the world. But in 1280 Europe was largely an intellectual backwater. It would be well over 300 years before Cambridge could boast a world-renowned scientist on its roster. The writings of the ancient Greeks were largely lost, and it was only after Toledo and its world famous library was conquered from the Moorish rulers of Andalusia and Southern Spain in 1085 CE that Europe was able to make strides in the various branches of knowledge thanks to the large number of Arab documents that now fell into the hands of the Spaniards at one of the greatest libraries of the middle ages. For example, Ptolemy's Syntaxis, which survives today as the Almagest (from the Arabic Al Majisti[4]) was translated into Latin from the Arabic reputedly by a Gerard of Cremona in 1175 CE. This was the sole text known as the Arabo Latin text in Astronomy for the majority of the people in Europe during the ensuing centuries, until the 17th century. In fact one cannot mention Ptolemy's Syntaxis without mentioning that there exist no manuscripts of this work dating back to the time when it was written (C.K. Raju[5]). Truth be told, it is wrong to refer to this text as Ptolemy's Almagest; rather it would be appropriate to call it Ptolemy's Syntaxis. One has to wait till the 9th century CE, for the translations into Arabic to happen. The credit for the Al Majisti should properly be given to the Arabic authors who compiled it. We place on record in Table 5 of chapter VIII, the lists of Islamic savants (only a minority of these were Arabs, and a predominant number were from Persia and Central Asia). The distribution of savants reflected the relative proportions of these people within the borders of the Islamic Khilafat. While we do not see the need for eulogizing the Islamic conquests, any more than we would eulogize the conquests of Alexander, or Ghenghiz Khan or Hitler, it remains a fact that the Islamic conquest challenged the Carolingian ruler Charles Martell in the West, after taking over most of the Iberian peninsula and it subjugated the mighty Persian Empire in the East. It brought an unintended benefit to the conquerors, which forms a significant part of our story. This was in the form of a resurgence of science, which flourished for more than 300 years. We will go into greater detail in Chapter VIII as to how it affected the story of Astronomy.

Throughout history, and especially thanks to the Arabs, the work of the Hindus was increasingly available to the Europeans. In 1068 CE Ṣāid al-Andalusī , as far as we are aware, the first historian of Science and as his name indicates from Moorish Spain, *wrote* ***Kitāb Tabaqāt al-Umam*** *in Arabic*

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[4] *Claudius Ptolemy called his work the Η Μεγαλη Συνταχιξ τηξ Αστρονομιαξ, Megaly Syntaxis, Great System of Astronomy. It was translated by Al Thābit ibn Qurra circa CE 880 after the Khilafat of the 7th Abbasid Khalīf Al Ma'amun and the name of the translation was Al Kitāb al Majisti, the Greatest Book. In the early years after the translation into Latin from the Arabic in the late 11th century or early 12th century, even as late as CE 1515 it was known as the Arabo Latin translation. The direct translation from the Greek was available only in the 16th century, from a Vatican manuscript. One wonders why the Vatican took 16 centuries to find this manuscript. The premise here is that only the Vatican had the means, motive, and opportunity to control the dissemination of such a well-known document. It is also a legitimate question to ask why the Almagest is always referred to as Ptolemy's Almagest, when in fact he never wrote a book with such a title.*

[5] *See CK Raju, Is Science Western in origin*

(Book of Categories of Nations, Livres des Categories' des Nations). The book was translated into French in 1835 by Regis Blachère[6] and into English by Alok Kumar[7] in 1992. The text was produced in Spain in the 11th century in which Şāid was reported to have made the observation that only eight nations were interested in and comprehended Science[8]. These eight people were the **Hindus, the Persians, the Chaldeans, the Jews, the Greeks, the Romans, the Egyptians, and the Arabs.** In this List, he placed the Hindus at the Head of the list because ***'Les Indous, entre tout les nations, a traversé le siècle et depuis l'antiquité, furent la source de la sagesse, de la justice et de la modération. Ils furent un peuple, donne de vertus pondératrices, créature de pensées sublimes, d'apologues universel d'inventions rares et de traits d'esprit remarquables',***

"*Among all nations, during the course of centuries and since antiquity the Indics were the source of wisdom, justice, and moderation. We credit the Indic nation and its people with excellent intellect, exalted ideas, universal maxims, rare inventions, and wonderful talents. They are indeed gifted with a trait characterized by a remarkable spirit.*

Şāid al-Andalusī (SAA) goes on to say "*To their credit, the Indics have made great strides in the study of numbers and of geometry. They have acquired immense information and reached the zenith in their knowledge of the movements of the stars (astronomy) and the secrets of the skies (astrology) as well as other mathematical studies. After all that, they have surpassed all the other peoples in their knowledge of medical science and the strengths of various drugs, the characteristics of compounds and the peculiarities of substances*.

This much is largely uncontested and it is abundantly clear that the high opinion that SAA had of Indic advances in the sciences was not an isolated instance. We mention Severus Sebokht, a Syrian Bishop, who studied astronomy, philosophy, and mathematics in the monastery of Keneshre on the banks of the Euphrates in 662 CE: (the following statement must be understood in the context of the alleged Greek claim that all mathematical knowledge emanated from them). Severus Sebokht was familiar with the work of Babylonian, Indian, and Greek science and was apparently irritated by the superciliousness of those who propagated the myth of the superiority of Greek learning.[9]

"*I shall not speak here of the science of the Hindus, who are not even Syrians, and not of their subtle discoveries in astronomy that are more inventive than those of the Greeks and of the Babylonians; not of their eloquent ways of counting nor of their art of calculation, which cannot be described in words - I only want to mention those calculations that are done with nine numerals. If those who believe, because they speak Greek, that they have arrived at the limits of science, would read the Indian texts, they would be convinced, even if a little late in the day, that there are others who know something of value"*[10]. But all of

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[6] *Régis Blachère Le Livre de la catégorie des Nations*

[7] *Şaid Al-Andalusi Science in the Medieval World: "Book of the Categories of Nations" (History of Science Series) (Hardcover) translated by , Semaan I. Salem (Author), Alok Kumar (Editor)*

[8] *Richter-Bernburg, Lutz (1987). Şāid, the Toledan Tables, and Andalusī Science. In From Deferent to Equant: A Volume of Studies in the History of Science in the Ancient and Medieval Near East in Honor of E. S. Kennedy, edited by David A. King and George Saliba, pp. 373–401. Annals of the New York Academy of Sciences, Volume 500.*

[9] *Nau, François, Journal Asiatique 3 (13) (1899): 56-101, 238-303.*

[10] *Nau, François. (1910) Notes d'astronomie indienne. Journal Asiatique 10 Ser. 16, 209 - 228. Needham, J. (1959) Science and civilization in China vol. ..www.es.flinders.edu.au/~mattom/science+society/lecture6.html. François Nau (May 13, 1864 at Thiel – September 2, 1931 at Paris) was a French Catholic priest, Mathematician and specialist in Syriac studies* Saad Al Andalusi work (Tabaquat al Umam) *dies and other oriental languages. He published a great number of eastern Christian texts and translations for the first and often only time.*

those high opinions of Indic science were anathema to the Colonial power that went to Herculean lengths to undermine the high reputation of the Indics and continues to do so even today.

We begin our story in Toledo because it seems clear in retrospect that the seed for Hellenization of all knowledge, the forerunner of today's Eurocentric view of the world, sprang from the vaults of the Toledo Library, when what was then largely Catholic Europe, discovered to their dismay that there were advances in almost every field, that they were not privy to. It was colonialism that provided a second wind to the process of Hellenization.

Colonialism is only a recent manifestation of Eurocentrism. It is not merely the conquest of dominion of vast lands and exerting one's will on millions of people. It is more than the act of unleashing unprovoked violence on a distant people, a violence not restricted to the physical realm. It subjects the colonized to an epistemic rupture of vast proportions. This is the narrative of one example of such an epistemic rupture. We will tell the story (and the history) of such a rupture in the case of Astronomy and Mathematics. We will amplify on what we mean by an epistemic rupture[11] in the following pages and recapitulate the status of the Indian in the modern era.

ȘĀID AL-ANDALUSĪ: ABŪ AL-QĀSIM ȘĀID IBN ABŪ AL-WALĪD AḤMAD RAHMĀN IBN MOḤAMMAD IBN ȘĀIDI AL-QURṬUBĪ. [12,13,14,]

Short Biography - The world's First Historian of Science
Born Almería, (Spain), 1029,*Died* Toledo, (Spain), July or August 1070
Șāid al-Andalusī was a Muslim historian, a historian of science and thought, and a mathematical scientist with an especial interest in astronomy, and until we see a name that supplants him probably the world's first historian of science. Following in the footsteps of his paternal family, Șāid pursued the career of a legal official, having received a solid education in the Islamic religious disciplines; in 1068, the Dhannūnid Berber Amīr of Toledo, al-Ma'mūn Yaḥyā (reigned: 1043–1075), appointed Șāid chief religious judge (qāḍī) of Toledo, an office his father had held earlier and that he himself was to fill until his death. What set him apart was his interest in history, history of science, and science itself, especially astronomy; here it may be recalled that in the present context "science" refers to what in pre-modern Islam often was termed "the ancient disciplines," viz. the syllabus of Aristotelian philosophy, logic, medicine, the mathematical sciences (including astronomy). Toledo, known in Arabic Tulaytilah became, as a result of the efforts of Yaḥyā, an important literary and intellectual center and it was here that Șāid wrote what has often been called his "history of science": Al-tariff bi-ţabaqāt al-umam (Exposition of the generations of nations) of 1068. The "nations" here intended are those said to have had a disposition toward the cultivation of learning, such as, Indians, Persians, Chaldeans, Egyptians, Greeks, al-Rūm ("Byzantines" and other Christians), Arabs, and Jews in contrast to the others not so disposed, i. e., Chinese, Turks, and Berbers. He has obviously high regard for the scientific prowess of the Indians, even though he lived in far off Spain. He made such a determination based on 3 texts, which were translated into

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[11] *Episteme, a system of understanding or a body of ideas which give shape to the knowledge of that time. We use the Term Vedic Episteme in the sense of the PramāṇEpisteme, a system of understanding or a body of ideas knowledge obtained through rigorous reasoning and includes such methods as Pratyaksha, Upamāna, Anumāna, Anupalabdhi, Arthāpatti, and Upapatti.*

[12] *Şāid al-Andalusī (1912). Kitāb ţabaqāt al-umam, edited by P. Louis Cheikho. Bierut: Imprimerie Catholique. French translation with notes by Régis Blachère as Livre des catégories des nations. Paris: Larose, 1935.*
[13] *(1985). Kitāb Ṭabaqāt al-umam, edited by Ĥayāt Bū _Alwān. Beirut.*
[14] *Khan, M R., IJHS, 30(2-4), 1995 Tabaqut Al-Umam Of Qaidi Said Al-Andalusi (1029-1070 CE)*

Arabic the Sindhind (by which we understand to be the Sūrya Siddhānta), the Arjabhar. (The *Āryabhaṭīya*) and the Arkand (Khandakādhyaka)[15]. He mentions he has received correct information only about Sindhind, which was translated and further developed by Al Fazari and AlKhwarismi amongst others. He does not speak of Al Biruni, even though Al Biruni predates him by a few decades.

A word is in order on the conventions associated with naming an individual in the Islamic world. A Muslim child will receive a name (called in Arabic ‘ism’), like Muhammad Husain, Thābit etc. After this comes the phrase ‘son of so and so’ and the child will be known as Thābit ibn Qurra (son of Qurra) or Muhammad ibn Husain (son of Husain). The genealogy can be extended for more than one generation. For example Ibrahim ibn Sinān ibn Thābit ibn Qurra, carries it back 3 generations to the great grandfather. Later he may have a child and may gain a paternal name (kunya in Arabic) such as Abū Abdullāh (father of Abdullāh). Next in order is a name indicating the tribe or place of origin (in Arabic **nisba**), such as al–Harrāni, the man from Harrān. At the end of the name, there might be a tag (**laqab** in Arabic), or nickname, such as the “goggle eyed” (al-Jahiz) or tentmaker (al-Khayyami), or a title such as the “orthodox” (al–Rashid). Putting all this together, we find that one of the most famous Muslim writer on mechanical devices had the full name Badī al-Zamān Abū al-ʻIzz Ismail al-Razzāz al-Jazarī. Here the **laqab** Badī-al-Zamān means Prodigy of the Age, certainly a title that a scientist would aspire to earn, and the **nisba** al-Jazarī signifies a person coming from al-Jazira, the country between the Tigris and the Euphrates Rivers. Thus there is considerable information encoded in the name of an individual that is useful from a historical perspective.

Uncovering the scope of Ancient Indian Mathematical Astronomy faces a twofold difficulty. To determine who discovered what and when, we must have an accurate idea of the chronology of Ancient India. This has been made doubly difficult by the faulty dating of Indic historical events by Sir William Jones who is otherwise credited with practically inventing the fields of modern linguistics and philology, if we make the reasonable assumption that he was not aware of the contributions of Pāṇini (Ashtādhyāyi) and Yāska (Nirukta) a couple of millennia before him. Sir William who was reputed to be an accomplished linguist, was nevertheless totally ignorant of Sanskrit when he arrived in India and proceeded in short order to decipher the entire history of India from his own meager understanding of the language. In the process he brushed aside the conventional history as known and memorized by Sanskrit pundits for hundreds of years as recorded in the Purāṇas and invented a brand new timeline for India which was not only egregiously wrong but also hopelessly scrambled the sequence of events and personalities. See for instance my chronicle on the extent of the damage caused by Sir William and his cohorts in my essay on the South Asia File[16][17]. But there should be little doubt in anybody’s mind that the subjects of linguistics and philology were a byproduct of the discovery of Sanskrit. The discovery of Sanskrit is often touted as a great achievement of the Europeans. It is obvious that it played a significant role in the manner in which the Occidental defined his own identity, and had a definite but significant impact in the manner in which they viewed the Indians. This contrived but highly negative image of the Indians was a major factor in the subsequent story that we have to tell. We are also of the opinion that Sir William played a major role in the shaping of the Indic mindset, but our reasons for doing so, do not part of the conventional narrative.

Kosla Vepa 5/13/2015 1:57 PM
Comment [1]: ,

It is not clear whether the error in chronology by Sir William was one caused by inadequate knowledge of language or one due to deliberate falsification of records. It is horrific to think that a scholar of the stature of Sir William would resort to



[15] *See for instance Berggren, J Lennart “Mathemati ... pt, Mesopotamia, China, India and Islam” A sourcebook, ed. b*
[16] *Vepa, K., The South Asia File, Original Publications, Delh*
[17] *Vepa, K. The Pernicious effects of the misinterpreted ... 9, available as vol.5 of the series on Distortions In Indian Hist*

skullduggery merely to satisfy his preconceived notions of the antiquity of Indic contributions to the sum of human knowledge. Hence we will assume Napoleon's dictum was in play here and that we should attribute not to malice that which can be explained by sheer incompetence. This mistake has been compounded over the intervening decades by a succession of British historians, who intent on reassuring themselves of their racial superiority, refused to acknowledge the antiquity of India, merely because 'it could not possibly be'. When once they discovered the antiquity of Egypt, Mesopotamia, and Babylon, every attempt was made not to disturb the notion that the Tigris Euphrates river valley was the cradle of civilization. When finally they stumbled upon increasing number of seals culminating in the discovery of Mohenjo Daro and Harappa by Rakhal Das Banerjee[18] and Daya Ram Sahni[19], under the directorship of John Marshall, they hit upon the ingenious idea that the Vedic civilization and the Indus Valley Civilization or the Sarasvati Sindhu Civilization, a more apt terminology since most of the archaeological sites lie along the banks of the dried up Sarasvati river, were entirely distinct and unrelated to each other. They went to extraordinary lengths to give the Harappans an identity that was as far removed from the rest of India as they could get away with. The consequences of such a postulate have been detailed in the South Asia File[20].

FIGURE 1 MOORISH AL-ANDALUZ COMPRISED MOST OF THE IBERIAN PENINSULA

There is also the Frawley Paradox[21]. There is the vast Vedic literature (see appendix D), but according to the current narrative of Ancient Indian History it has no location much less an archaeology associated with it. And the Sarasvati Sindhu civilization which has an immense amount of archaeology spread over 1.5 million square miles covering 2/3rd of the western half of the Indian subcontinent but according to the conventional wisdom has hardly any literature. The juxtaposition of these 2 artifacts occurring for part of their respective histories congruently in time and space should have suggested that Ockham's razor is again a logical alternative and that the Harappan civilization is a late stage of the Vedic civilization, perhaps the mature stage of the Sulva Sūtra era. Why do we say this? Because fire altars were found in the sites of the Sarasvati that would necessitate the use of geometry developed in the Sulva Sūtras. But such an answer would vault the Indic civilization to the top of the totem pole of civilizations ranked according to antiquity and the prevailing colonial mindset was to squash such ideas since they gave the Indic civilization an antiquity higher than most other civilizations and that simply would not do. In any event we cannot afford to digress anymore in this direction, other than to suggest that examples of the use of Sulva Sūtra Geometry can be found in more than one location. The second difficulty was the Euro centricity (a euphemism for a clearly racist attitude) of European mathematicians, who refused to appreciate the full scope of the Indic contributions and insisted on giving greater credit to Greece and later to Babylonian mathematics rather than recognize Indic and Vedic mathematics on its own merits as an independent effort with distinct and unique characteristics. If this was indeed a surprise revelation, I fail to see the irony, when a similar Euro centricity was exhibited towards the antiquity of the Vedic people themselves.

Euro centricity pervades the thought processes of the Occidental and distorts his vision to such an overwhelming degree, that the resulting periodization adopted by Otto Neugebauer (ON) in ONHAMA[22]

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[18] See Glo-pedia
[19] Rai Bahadur Daya Ram Sahni, (1879-1939) initiates the first extensive excavations at Harappa in 1920 under the general direction of John Marshall.
[20] Vepa, K., op.cit.
[21] Named after David Frawley see for instance In search of the cradle of civilization, Wheaton, Illinois, Quest Books, 1995
[22] ONHAMA, p.2

TABLE 1 SPECIFICATIONS FOR A USEFUL AND EASY TO USE CALENDAR
The Civil year and the month must have an integral number of days.
The starting day of the year and the month ought to be consistently defined. The dates should correspond to the seasons of the year.
For the purpose of continuous dating, an era should be used and should be properly defined.

where he adopts 700 BCE as the starting point for his deliberations, is completely irrelevant to the reality of the situation.

There is a fundamental difference in the Weltanschauung of the Occidental versus the Vedantic concept of the heritage of humankind. The Vedantin regards the Universe as his playground and he rejoices in the triumphs of the human spirit unfettered by limitations of geography and race and identity politics. The primary consideration of the Occidental appears to be to ensure his primacy and the priority of his civilization. This is not to say that every Indic subscribes to the Vedantic ideal, but such ontology is rarely subscribed to in the west and perhaps is the likely explanation for the obsession that the Occidental has exhibited to claim priority in every field of endeavor and manufacture a competitive antiquity however incredible the resulting conclusions may be.

The Occidental has tried his best to prevent us from seeing the Indic civilization in its totality, by denying us the autochthonous origin of various disciplines. He was extraordinarily vehement in defining the new Chronology and was careful that no discovery should be attributed to India prior to the Golden age of Greece. And soon it became an axiom of Indic thought that we had borrowed everything from the Greeks and Indians today are caught in the web of a circular argument, where we assume the answer to the question 'when did the Indics discover this. Typical of such Indian writers (and almost no Indian writer has challenged the basic steel frame of the Indian chronology of Vincent Smith) was Gaurang Nath Banerjee who wrote about Hellenism in Ancient India, which was obviously written to placate occidental sensibilities in 1920.

The civil day, as distinguished from the astronomical day should be defined. While the use of an astronomical day was appropriate during the ancient era, the requirements of precision demand an objective measure that is independent of the variability of the so called astronomical constants. We draw attention to this to see if any of the ancients were perspicacious enough to see this, 5000 years ago. If a Lunar month is part of the design of the calendar, there should be convenient and elegant means to make luni solar adjustments.

There is a reason why we should rely heavily on the works of Indic astronomers, apart from telling us what they knew, they were quite precise in dating their own period and by making observations of the sky enabled us to date an event with remarkable precision.

But we are getting ahead of ourselves and we need to ask ourselves, as historians, when and how the transformation of Europe and in particular the island nation of Britain took place, from a scientifically backward region of the world to the technologically most advanced one, all in the space of less than 500 years. We contend that theft of intellectual property played a very large role in this transformation. What constitutes theft? Generally the reluctance to divulge the source of the information is reason enough. Over the years the memory of this massive borrowing (and theft) from the non-European parts of the universe has been largely suppressed by many deliberate acts. The Vatican institutionalized such larceny in a papal bull, in the 15th century Law of Christian Discovery[23]ordinary European today does not have an awareness of the appalling conditions in Europe prior to the renaissance and the widespread illiteracy and backwardness that was prevailing during the 16 centuries between the virtual eclipse of the Grecian civilization (the end of the Ptolemy's), when Ptolemaic Egypt was subjugated by Rome and the beginning of the renaissance, which was coincident with the conquest of Meso America.

We pick the example of calendrical astronomy or the history of the calendar to illustrate the extraordinary lengths that the occidental would resort to, in order to deny the astronomical heritage of India. The occidental does not deny that there were extensive contacts between Greece and India especially after the invasion of Alexander, but he is loath to admitting the possibility that any of this happened to the benefit of the Greeks. The study of the calendar and astronomy in our view forms a canonical example of how a colonial power was able to undermine the self-esteem of an entire civilization, by creating a psychosis of inadequacy amongst the elite of its people. So thorough was this alteration of the mindset of the Indic that its aftereffects are being felt in a myriad ways even 60 years after the colonial power has left the scene. One of these aftereffects is the obliteration of the native achievements in mathematics and astronomy in the collective memory of the Indic civilization. Very few

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[23] *Under various theological and legal doctrines formulated during and after the Crusades, non-Christians were considered enemies of the Catholic faith and, as such, less than human. Accordingly, in the bull of 1452, Pope Nicholas directed King Alfonso to "capture, vanquish, and subdue the Saracens, pagans, and other enemies of Christ," to "put them into perpetual slavery," and "to take all their possessions and property." Acting on this papal privilege, Portugal continued to traffic in African slaves, and expanded its royal dominions by making "discoveries" along the western coast of Africa, claiming those lands as Portuguese territory.*

Thus, when Columbus sailed west across the Sea of Darkness in 1492 - with the express understanding that he was authorized to "take possession" of any lands he "discovered" that were "not under the dominion of any Christian rulers" - he and the Spanish sovereigns of Aragon and Castile were following an already well-established tradition of "discovery" and conquest. [Thacher:96] Indeed, after Columbus returned to Europe, Pope Alexander VI issued a papal document, the bull Inter Cetera of May 3, 1493, "granting" to Spain - at the request of Ferdinand and Isabella - the right to conquer the lands which Columbus had already found, as well as any lands which Spain might "discover" in the future. Eventually the law of Christian Discovery was adopted by the USA in 1823, in order to give legal sanction to the theft of land from the Native Americans. This law of Christian discovery included the right to claim discoveries made in the sciences in the conquered and colonized lands. Thus it was that genocide and theft of intellectual property was sanctioned by the highest authorities in the occident.

among the Indics are familiar with the vast scope of the ancient Indic episteme in this field of endeavor. The attempt to pass of all the work done in India as a pale copy of the Greek heritage is one that the Colonial Power has had a fair amount of success, since a majority of the English educated elite in India has bought into this notion. This is the story of how they did it in Mathematics and Astronomy, but it is clear that the damage is far more extensive and spans the entire gamut of human activity. There are lessons to be drawn from this sorry tale. The redeeming feature of this narrative is the expectation that future generations will be convinced that what had been accomplished in the millennia that the civilization has been active, can be a guiding principle for the future and that the Indic will not repeat those actions which had led to the loss of control over his own destiny.

THE CALENDAR AND ASTRONOMY

A calendar is a system for temporally organizing events in our daily life for social, religious, commercial, or administrative purposes. This is done by giving names to periods of time, typically days, weeks, months, and years. The name given to each day is an integer, known as a date. Periods in a calendar (such as years and months) are usually, though not necessarily, synchronized with the cycle of the Sun or the Moon. Many civilizations and societies have devised a calendar, usually derived from other calendars on which they model their systems, while ensuring that it is suited to their particular need. Calendars in the world utilize the periodicities of the repetitive motions associated with the Solar system, especially those that can be established with the use of the naked eye. It is remarkable that different societies have come up with similar, though not identical paradigms in designing their calendars. In retrospect, it is not really surprising that this should be the case, since they use essentially the same parameters associated with the motions of the Sun and the Moon.

A calendar is also a physical device (often paper). This is the most common usage of the word. Other similar types of calendars can include computerized systems, which can be set to remind the user of upcoming events and appointments. As a subset, a *calendar* is also used to denote a list of particular set of planned events (for example, court calendar). The English word *calendar* is derived from the Latin word *kalendae*, which was the Latin name of the first day of every month, when debts fell due and accounts were reckoned -- from calare "to announce solemnly, call out," as the priests did in proclaiming the new Moon that marked the calends. Regardless of the context or the region where the Calendar first got initiated, the design of a Calendar has never been a mathematically elegant exercise. This is so because there are not an exact number of days in either the Lunar month or the Solar year and there are not an integer number of months in a year. To put it in pithy terms, these quantities are not commensurate with each other.

To summarize the objectives of designing a calendar;

- **To administer the civic and regulatory needs of a people**
- **To regulate the socio religious activities of society**

The need for a calendar was felt very early in recorded history, especially after the advent of river valley civilizations and soon the quest began to predict the regularity of the seasons, in order to plan ahead for planting the crops. It was realized that there was regularity in the motion of the heavenly bodies that gave an indication of such repeated occurrences as the seasons. It is for this reason that the connection between the calendar and astronomy was established at an early stage of human development, beginning with the formation of river valley civilizations.

As a result of the lack of exact relationships between integers representing the various periods, the Indic (and I suspect others such as the Babylonians) were compelled to develop mathematical techniques suitable for handling large quantities. And the inability to express relationships using merely whole numbers or integers forced the Indics at a very early stage in their development to postulate a decimal place value system, with the use of zero as the number whose value is dependent on its place. Nevertheless, the facility with large numbers which we take for granted today was not universal in the ancient world and Ptolemy[24] himself expressed difficulty dealing with fractions[25] and of course we know that the Occident did not use decimals till about 1000 years later. This leads us to wonder how Ptolemy was able to carry out the arithmetical operations needed in the Syntaxis in 160 CE especially when he admits that he had no facility with fractions.

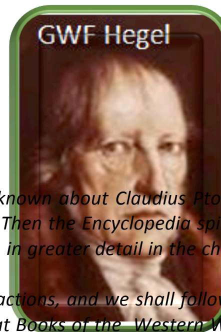
The Indic approach to astronomy, contrary to presuppositions in the occident was characterized by mundane motivations namely the need to determine accurately the date, time and place of the location of the main planetary bodies that he could see with the naked eye; the Sun, Moon, Venus, Mercury, Mars, Jupiter and Saturn in relation to the Earth. As we shall repeat on more than one occasion, in this endeavor he was eminently practical. Again, his motivation for the determination of these quantities was also driven by pragmatic considerations like a need for fixing the seasons when planting was necessary. He may have found it politic to cloak these mundane considerations in ritualistic garb in order to impress those in society not blessed with the analytical skills that he may have used. In summary the goal of the Ancient Indic Prayojana or raison-de-être of the Ṡāstra was primarily the determination of Kalá (Time), Dik (direction or orientation), and Desha (Place) or what is customarily referred to as the **Triprasna Adhikāra**.

The story of the calendar and the development of mathematics and astronomy is indeed a fascinating chapter in the intellectual history of the species. It is laced with people of superior talents, but all too often these very same gifted individuals were not able to rise above petty considerations, while they were uncovering the secrets of the skies. I trust I can make it as exciting a tale as I discovered it to be during my researches.

O NEUGEBAUER AND THE HEGELIAN HYPOTHESIS

It is unfortunate that the Indic role in this fascinating chapter has been largely ignored[26] in most western descriptions of the history of astronomy and time. There hardly exists a history book in Astronomy that does justice to the fact that the ancient Indians left behind a staggering amount of literature[27] for us to decipher. In fact the perception is just the opposite; that Information about Indian mathematics is hard to get. This is in large part a problem that western historians have created by imposing unreasonable standards of reliability.

FIGURE 2 GWF HEGEL



[24] *Then, there is the small detail as to the identity of Ptolemy. Almost nothing is known about Claudius Ptolemy, according to the Encyclopedia Britannica, 1966 edition, volume 18, and page 813. Then the Encyclopedia spins an elaborate tale of this individual, about who very little is known. We will discuss him in greater detail in the chapter on comparative study of Greek and other astronomies.*

[25] *"In general we will use the sexagesimal system, because of the difficulty with fractions, and we shall follow out the multiplications and divisions "Ptolemy, translated by R Catesby Taliaferro, Great Books of the Western World, vol.15, Encyclopedia Britannica, Chicago , 1996., P.14,*

[26] *See for instance, James Evans, The history and practice of Ancient Astronomy, Oxford University press, New York,1998*

[27] *David Pingree, Census of the Exact Sciences in Sanskrit (CESS) five volumes, American Philosophical Society, Philadelphia,1970.*

In many cases the standards were impossible to meet, especially as researchers were hampered in their due diligence work because of inadequate knowledge of Sanskrit. On the other hand, these standards were never demanded of similar sources from Ancient Greece. As a result the bias against Indic contributions in antiquity has been institutionalized to a large degree.

This is regrettable and as a result, the story within a story of how the occidental tried to ignore, minimize, and even suppress the Indic contribution is equally interesting. We do not propose to be equally as parochial as the Occidental has chosen to be for the most part, in his accounts of the history of time and astronomy, and we propose to be respectful of the contributions of other civilizations be they Babylonian, Chinese or Maya [28]. It is vital to realize that we are not talking about the contributions of a handful of individuals but literally scores of mathematicians and astronomers. The table of savants in the field of Astronomy and Mathematics in Chapter XI gives an idea of the large number of contributors in one area alone.

Thus, the study of the Indic contribution to the Computational Sciences has languished under a diminished set of extreme alternative hypothesis, one of which asserts that everything that the Indic developed in the exact sciences, was borrowed from Greece (or Babylon). Such an oversimplification is a familiar tactic used in denigrating one's adversary, and is known as Reductionism. The underlying assumption is that India has been for the most part a cultural cul-de-sac, where nothing new originated. This is what we term the Hegelian Hypothesis[29] and it has been the fundamental assumption that most historians from the Occident have adopted largely ignoring the vast amount of Indic literature, where it was not consistent with their hypothesis. The counter to this is the hypothesis that all knowledge is contained in the Vedas and that it needs merely to be deciphered. It bears emphasizing that the later hypothesis has almost a zero set of subscribers in India, while the former is adhered to rather dogmatically by the vast majority of the so called mainstream historians and philologists of India[30] from the Occident. It is important and relevant to mention that there are no assumptions made in the Vedic paradigm, which even remotely approach the exclusivity that remains a hallmark of the Occidental belief

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[28] Space considerations preclude us from doing equal justice to all traditions, in which case we will have to restrict ourselves to point to other treatments of the subject mentioned in our extensive bibliography in appendix G,H

[29] Georg Wilhelm Friedrich Hegel (August 27, 1770 – November 14, 1831) was a German philosopher born in Stuttgart, Württemberg, in present-day southwest Germany. His influence has been widespread on writers of widely varying positions, including both his admirers (F. H. Bradley, Sartre, Hans Küng, Bruno Bauer, Max Stirner, Karl Marx), and his detractors (Kierkegaard, Schopenhauer, Nietzsche, Heidegger, Schelling). He introduced, arguably for the first time in philosophy, the idea that History and the concrete are important in getting out of the circle of Philosophia Perennis*, i.e., the perennial problems of philosophy. He also stressed the importance of the other in the coming to be of self-awareness (see master-slave dialectic).*

We are primarily concerned here with his ideas on Indic studies. The invasion theory of Indian History was first postulated by Hegel in his Philosophy of History that India lacked historical agency and that India was a cultural cul de sac from which nothing worthwhile ever emanated.

'It strikes every one, in beginning to form an acquaintance with the treasures of Indian literature, that a land so rich in intellectual products, and those of the profoundest order of thought, has no History. 'Hegel, G. W. F. (1956). The Philosophy of History, translated by J. Sibree, New York, Dover Publications, Inc.

[30] It is relevant to point out that the large majority of historians of India who were born in Britain, were Civil servants either of the East India Company or members of the Indian Civil Service (ICS) who ruled India on behalf of Whitehall and the India office in London They had neither the accountability nor the motivation to tell the true history of India, and we understand that such an ethical code of conduct is perhaps too high a burden to bear for the men who were entrusted to keep the empire in Britain's possession for a long time to come. While we understand the compulsions under which they wrote their books on History, we feel that such a mercenary association automatically disqualifies them from being classified as dispassionate scholars interested only in the truth.

systems. The enthusiastic acceptance of diversity remains the core of the Hindu ethos; Hindu tattva or what is popularly referred to as Hindutva.

We find it particularly incongruous that the Occidental sits in judgment over the Hindu, especially dismayed by the confidence, characterizing the resurgence and renaissance of the Hindu, given his own dismal record of culpability in the genocide and obliteration of native cultures in Meso America, not to mention the numerous inquisitions, pogroms and genocide that he frequently indulged in. People who live in glass houses should not throw rocks at others. I mention this because any assertion made regarding Indian history that does not toe the line and adhere to the mainstream version of History, as recounted by the steel frame of India, the East India Company officers and the Indian Civil Service (ICS) officers who in large part rewrote the current revision of the history of India, is immediately dubbed as being a 'fundamentalist'. It is pertinent to ask what and who the fundamentalist is? We give a definition of a fundamentalist in the glossary. In order to qualify as a fundamentalist[31], one must publicly advocate violence against innocent bystanders, including women and children. One cannot brand an individual a fundamentalist merely because he entertains a violent thought. We can only presume that their use of the word fundamentalist in this context is meant merely for diversionary purposes, and is irrelevant to the substance of the argument and whether the alternative chronology that we propose has merit or not.

THE PROBLEM WITH THE OCCIDENTALIST CHARACTERIZATION OF OTHER CULTURES AND CIVILIZATIONS

In my view there are 2 fundamental problems with the current characterization of India in the context of the history of the computational sciences

1. The fundamental problem bedeviling the proper narration of the Indic contribution to the sciences in antiquity is the lack of basic knowledge of the Sanskrit Grammar and language amongst historians of science in the occident. I am not speaking about the Professors of Sanskrit in the USA who for the most part are capable of translating Sanskrit texts into European languages. But such linguistic skills in the Sanskrit language are rarely present amongst most historians of science. The result is that they tend to ignore the vast literature of ancient India, have little cognizance of the subtle etymologies of Sanskrit words and even in the rare instance that they refer to the Indian work they resort to the circular argument of referring to other authors who exhibit an equally high degree of functional illiteracy in Sanskrit. Most, even when they claim to be a Sanskrit scholar are barely able to demonstrate proficiency in the language. Rarely will these scholars make a disclaimer that he or she is incompetent to judge the contribution of India, because of inadequate knowledge of Sanskrit. Neugebauer is one of the few exceptions, when he eludes to this in the introduction to his 'A History of Ancient Mathematical Astronomy'[32]. Even such a limited caveat is absent in the books I have cited on the history of astronomy.

2. The other fundamental problem is the faulty chronology that he has bestowed upon India. It does not matter whether this was deliberate or inadvertent. The myopic Eurocentric view that has become the "accepted" doctrine has had serious repercussions for the historian of science studying other cultures.

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[31] The principle we are adhering to, in making such a distinction is that it is not merely sufficient to entertain the thought of violence but one must publicly advocate the practice of violence, in order to qualify for applying such a pejorative to an individual. If we punished every person in the populace for entertaining unsavory acts, there would not be anybody left to enforce thru punishment.

[32] Otto Neugebauer A History of Ancient Mathematical Astronomy' Springer-Verlag, 1975ISBN038706995X, 9780387069951Length 9780387069951. Length 1456 pages. A limited preview of this extremely expensive book is available in Google Books .on the web.

By postulating the impossibly late migration of a mythic race of people the present narrative has completely garbled the entire history of India. It is easy to understand the British rationale behind such a narrative when several historians were paid to write such a history in the nineteenth century. The idea was to project that the English were simply the latest in a string of invaders to have invaded the subcontinent and have therefore as much right to rule over you as the intellectual leadership of the country who have been the real exploiters of the common folk. Never mind that the Colonial power ruled over India with an Iron fist (e.g. No Indian could own firearms) and the only person who could exploit the Indians was the colonial overlord. It made a good story and provided the Indians with a punching bag that was within their ambit. By inventing and making the late arrival of the mythic Āryans a fait accompli, the narrative killed several birds with one stone. Indian chronology became a hostage to the "late arrival" of the Indo Āryans that leads to the coup de grace. Because of this late arrival he the Indo Aryan could not have developed anything worthwhile before the Greeks and the Babylonians. We are aware that victors write the history of a vanquished nation. But naïve as the Indics were, they did not dream that the resulting story would be so diabolically different from reality. Implicit in all this is the racist notion that only the Indo Āryans (a euphemism for Europeans) were capable of undertaking the truly hard tasks – the development of Sanskrit, the development of astronomy etc.[33, and 27]

It is true that knowledge grows exponentially with time and it would be the height of folly to take the position that the books of the Vedic age contain all knowledge developed since then, and need merely to be deciphered. We emphasize repeatedly in these pages that the reason that we seek to decipher the true history, is not solely to claim priority over inventions or to seek glory in the reflected greatness of a high antiquity during a bygone era. Our position is refreshingly different from that of the Occidental who takes great pride in adopting to piggyback on the heritage and antiquity of the most ancient urban civilization in their neighborhood, namely that of the Greeks.

THE FAITHFUL TRANSMISSION OF THE COMPUTATIONAL SCIENCES

The importance that various civilizations have placed on the faithful transmission of the computational sciences such as mathematics and astronomy is clearly articulated by Otto Neugebauer (ON) in the introduction of his classic on 'The exact sciences of Antiquity'[34]. An extensive quote is in order here;

'*The investigation of the transmission of mathematics and astronomy is one of the most powerful tools for the establishment of relations between different civilizations. Stylistic motives, religious or philosophical doctrines may be developed independently or can travel great distances through a slow and very indirect process of diffusion. Complicated astronomical methods, however, involving the use of accurate numerical constants, requires for their transmission the direct use of scientific treatises and will often give us very accurate information about the time and circumstances of contact. It will also give us the possibility of exactly evaluating the contributions or modifications, which must be credited to the new user of a foreign method. In short the inherent accuracy of the mathematical sciences will penetrate to some extent into purely historical problems. But above and beyond the usefulness of the history of the exact sciences for the history of civilization in general, it is the interest in the role of accurate knowledge in human thought that motivates the following studies.*'

We are in agreement with Neugebauer, that one does not need a rationale other than the search for an accurate narrative. The search for the truth is an end in itself. We are also in agreement

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[33] Kosla Vepa "The South Asia File"

27 Kosla Vepa "The Pernicious Effects of a Misinterpreted Greek Synchronism" Paper presented at the ICIH2009

[34] Otto Neugebauer "The Exact Sciences in Antiquity" first published in 1957 by Brown university press, republished by Dover publications, New York, NY, in 1967

with him on the central role that the history of the mathematical sciences should play and should have played in the development of the history of civilization in general, clearly implying that they have not done so in the past. We have gone into some of the reasons for such a state of affairs later in this chapter.

Neugebauer concedes that independent development of ideas could occur, but he is clearly asserting that such cannot necessarily be the case when it involves complex calculations, and the use of accurate astronomical constants. In those cases he asserts that there must have been direct transmission of knowledge. But it is clear that when it comes to India the application of this principle has been very one sided. Wherever there has been little dispute about the priority of the Indian invention, (and the Occidental has made every effort to pare down such instances to an absolute minimum), he and others of his Parampara[35] (notably David Pingree) have pleaded that there was an independent invention by the Europeans, but in those instances where the reverse was the case, he has unhesitatingly and unequivocally declared that the Indic has borrowed from the west and has assumed that the Indic should not be credited with independent invention. He clearly violates his own prescription that such an independent development (in this instance in the west) is very unlikely in the mathematical sciences. The transmission to the east, particularly to India has been assumed to occur even when they have not been able to identify the person or mechanism by which such a transfer occurred. This has been the case in almost every instance in which the occidental claims that there was transmittal of knowledge from Europe to India. The occidental clings to this dogmatic belief even when he knows he cannot indicate a single instance where he can identify the person or persons who made the transfer of knowledge. We will allude to this later in the introduction. Thus, even as great a scholar that he was, Neugebauer succumbs to the prejudice of Euro centrism when he makes the categorical statement that:

"*The center of "ancient science" lies in the "Hellenistic" period, i.e., in the period following Alexander's conquest of the ancient sites of oriental civilizations (Frontispiece of his book). In this melting pot of" Hellenism" a form of science was developed which later spread over an area reaching from India to Western Europe and which was dominant until the creation of modern science in the time of Newton. On the other hand the Hellenistic civilization had its own roots in the Oriental civilizations, which flourished about equally before Hellenism as its direct influence was felt afterwards. The origin and transmission of Hellenistic science is therefore the central problem of our whole discussion*. "

By so doing he has made an axiom, a postulate of something, which he needs to establish. We are somewhat puzzled by the repeated use of the term Hellenistic by Neugebauer, since most of the scientific developments took place initially in the little islands of the coast of Asia Minor in present day Turkey, beginning with Thales of Miletus, and subsequently in the mixed Greco-Egyptian civilization of the Ptolemaic Pharaohs at Alexandria. The Greeks of Asia Minor included Anaximander, Aristarchus of Samos, and *Hipparchus* or Hipparchus (Greek: Ἵππαρχος, Hipparchus; c. 190 BCE – c. 120 BC) were known as Ionians and of course the Alexandrian Greeks such as Eratosthenes and Ptolemy were heavily influenced by the Egyptian episteme and should be regarded as belonging to the Egyptian Darśanas

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[35] *Parampara (Sanskrit: परम्परा, parampara) denotes a succession of teachers and disciples in traditional Indian culture. It is also known as guru-śiṣya parampara, succession from guru to disciple. In the parampara system, knowledge (in any field) is passed down (undiluted) through successive generations. The Sanskrit word literally means an uninterrupted series or succession.[1] In the traditional residential form of education, the śiṣya remains with his guru as a family member and gets the education as a true learner. In some traditions there is never more than one active master at the same time in the same guruparamparya (lineage). The fields of knowledge taught may include, for example, spiritual, artistic (music or dance) or educational. See for instance the Glo-pedia in Appendix A*

(Philosophical episteme) and Parampara (a particular tradition followed by an educational institution). In fact Neugebauer seems to contradict himself when he says in one of his endnotes.

In our discussions we have frequently used the word "Greek" with no inherent qualification. It may be useful to remark that we use this term only as a convenient geographical or linguistic notation. A concept like "Greek mathematics", however, seems to me more misleading than helpful. We are fairly well acquainted with three mathematicians -Euclid[36]*, Archimedes, and Apollonius -who represent one consistent tradition. We know only one astronomer Ptolemy. And we are familiar with about equally many minor figures that more or less follow their great masters..*

What Neugebauer says about transmission of Mathematical and Astronomical knowledge resonates very appropriately in the case of the ancient Indic. But there is more to the statement that Neugebauer makes than mere availability of Greek documents. It is the inability to do simple arithmetic that made Greek works obsolete and made them dispensable and hence not worth preserving. We quote C.K. Raju[6];

Ever since state and church first came together, at the time of Constantine, Eusebius, a church historian, had initiated the program of distorting history to promote church interests. His successor Orosius, in his History against the Pagans, made it amply clear that history was just another tool of soft power in the church's armory. This technology of falsehood was now applied to "manage" common perceptions. The story line was simple: it was the Greeks who did it. On this story, during the 600 years of the Christian Dark Age, all that the Arabs did was to preserve Greek works, the rightful inheritors of which were the chosen people, the Christians of Europe.

It was this fantastic justification—characterizing Arabs as mere carriers of knowledge, and Greeks as the creative fount —which made the ("Greek") knowledge in Arabic books theologically acceptable in Europe, and enabled the translated Arabic books to be used as university texts for centuries in Europe. Arabs did not quite accept this story. In the 9th Century, when the Arabs built the Bayt al Hikma (House of Wisdom) in Baghdad, they gathered knowledge from all over the world, including India, Persia, and China. ***They certainly did not restrict themselves to Greek sources. The actions speak for themselves: the Arabs did not then think, nor do they concede to this notion today, that science was primarily a Greek invention.***

While speaking about the origins of the Calculus, Richard Courant, the guru of ON at Göttingen, makes the following perspicacious remark "*With an absurd oversimplification, the "invention" of the calculus is sometimes ascribed to two men, Newton and Leibniz. In reality, the calculus is the product of a long evolution that was neither initiated nor terminated by Newton and Leibniz, but in which both played a decisive part. Scattered over seventeenth century Europe, for the most part outside the schools, was a group of spirited scientists who strove to continue the mathematical work of Galileo and Kepler."*

While he is right about the inordinate emphasis on assigning credit and priority that the Occident has placed on the development of such subjects as Calculus and the myopic emphasis on granting these 2 individuals the entire responsibility and credit for developing the Calculus, Richard Courant is unable to see that he is part of the problem, when he restricts himself to seventeenth century Europe as the primary actor in this drama. It is clear that in expecting even a small number of Europeans to take the

[36] It is important to remind our self that Euclid to a greater extent than Ptolemy is a very elusive character in Greek history and it is not known with any degree of certainty whether such a person really existed and even less is known about his chronology. See the work of CK Raju documented in CFM

unconventional view that Asia and in particular India had a significant part to play in this, we are asking for something that is simply not there and will prove to be a task where success may be elusive and even if it comes, will be a grudging one. But that does not mean the attempt to tell the truth should not be a relentless one and should not cease until there is genuine recognition of the substantial Indic contribution.

GREEK AND ROMAN DIFFICULTIES WITH ELEMENTARY ARITHMETIC

Quote[37]**"***The non-textual evidence provides a good reason for assuming that the Greeks and the Roman had inordinate difficulties with elementary arithmetic. More than deduction, science is based on quantitative calculation. But the Greeks lacked basic arithmetic skills needed for calculation. The early Greek (Attic) system of representing numbers was worse even than Roman numerals. (We will use Roman numerals in the following examples, since they are better known.) Greek/Roman numerals are inefficient for two reasons. First they are clumsy: the small number 1788 requires 12 symbols, and is written as MDCCLXXXVIII. This system is hopeless for large numbers, such as* 10^{53}*, which the Buddha was asked to name (by an opponent, who sought to test his knowledge*[38]*). The world might come to an end before one finishes writing down this number in Roman numerals! The unavoidable inference is this: the Greeks and Romans used this primitive system of numeration just because they never encountered large numbers, and never did the complex calculations required for astronomy and science. Conversely, when the need for such complex calculations arose in Europe, first among the Florentine merchants, and then among European navigators, Roman numerals were abandoned in favor of "Arabic numerals".*
Can one get around this inefficiency by inventing names for larger numbers? No. Roman numerals are structurally inefficient: even the simplest sum needs an abacus. Try XIV + XVIII! To add two numbers, say 1788 + 1832, one would first represent these numbers on the Roman abacus, using counters.

Multiplication is more difficult. Shakespeare's clown knows that 11 sheep give 28 pounds of wool, which sells for a guinea. How much would he get for the wool from 1500 sheep? He "cannot do it without counters". (We leave out subtraction and division as too difficult to explain!) The Greeks obviously could not have done science without properly knowing how to add and multiply ".
So, the conclusion is inescapable. If Ptolemy, by his own admission[39] could not carry out simple operations with fractions, how did he carry out all the arithmetical operations needed throughout the book, starting with the table of chords in the 2nd century CE?

In order to understand the Indic approach to the challenges faced by the human, one must understand the cosmology and the calendar of the Hindu. The calendar and the cosmos have always played a large part in the consciousness or Weltanschauung of the Hindu and he spent a large portion of his

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[37] Raju, CK, Is Science western in Origin, Page 9. For a more comprehensive treatment we strongly recommend a detailed study of The Cultural Foundations of Mathematics (CFM) by the same author. The complete citation is available in the Appendix under Primary and other sources. A massive amount of forensic research has gone into the writing of this book, most of which is not easily available elsewhere.
[38] See Appendix O, regarding the Indian penchant for large numbers
[39] The Almagest by R Catesby Taliaferro, Book I, Chapter 10, P.14. "In general we shall use the sexagesimal system because of the difficulty of fractions, and we shall follow out the multiplications and divisions, aiming always at such an approximation as will leave no error worth considering as far as the accuracy of the senses is concerned. The translator claims that sexagesimal arithmetic is easier to do than decimal arithmetic. I fail to see why that is the case. If Ptolemy could not do fractions, he is unlikely to have found that it is easier to deal with 53/60 vs. 7/10.

observational powers in deciphering the universe around him. In this he was not alone, as we know now that other ancient civilizations, such as the Babylonian, the Egyptian, and the Chinese had similar interests and a curiosity about the heavens. But the answers the Indic came up with were quite prescient for his time, and the resulting numbers were far more accurate than the European world realized or knew, even millennia after the Indic discovered these periodicities.

In the rest of this work, we will prefer to use the adjective Indic more as a Geographic identifier rather than the word Hindu that would subsume considerable work done by Buddhists and Jainas in the subcontinent. As neither of these words was widely used in the ancient era, such a distinction is not of great consequence, while we are mindful of current sensibilities regarding inclusiveness. While there are minor differences between the approaches of the Jaina and the Bauddhika Parampara, these differences are insignificant when compared with work in the same field by others such as the Chinese, Babylonians, and Greeks.

STUDY INDIA FOR THE GREATER PART OF YOUR LIFE AND MINIMIZE THE INDIC AD NAUSEUM

The extraordinary allergy that the Occidental, with a few notable exceptions, has exhibited to the serious, unbiased, and scholarly study of the Indic mathematical episteme, and when he has done so, the vehemence with which he has denied the value of these traditions, is astonishing to say the least. In those instances where the Occidental has recognized their value, and has used the resulting knowledge in his subsequent investigations, he has tried his best to assert initially that it was plagiarized from the Greeks and later from the Babylonians, when the relative chronology of the Indics and the Greeks indicated that such a hypothesis was a non -sequitur. When the Babylonians were discovered as having been the main progenitors, he immediately inferred that the Indic had absorbed this knowledge from the Babylonians. When such a stance became more and more difficult to sustain, he maintained that it was not autochthonous to the subcontinent but brought in from elsewhere by the largely mythic people called the Āryans. The consistency with which the Occidental has denied the Indic contributions especially those which imply a terminus ante quem of high antiquity, is exemplified in the writings of various Indologists such as Whitney[40], Bentley[41], Moriz Winternitz,[42] Albrecht Weber[43], W. W. Rouse Ball,

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[40] American Indologist. One of Salisbury's students at Yale, William Dwight Whitney (1827-1901) went on to become the foremost Sanskrit scholar in the continental US, having studied in Berlin under alleged German scholars as Bopp and Weber. One would have thought that to become a Sanskrit scholar, one should study under the great masters and pundits of India. But like Weber, Whitney became one of the principal detractors of the notion that anything worthwhile came out of India especially in the field of Astronomy. Whitney became a full professor of Sanskrit language and literature at Yale in 1854, wrote his classic Sanskrit Grammar (1879), and was the doyen of Indologists of his period. Like many in the occident, who considered themselves expert in Sanskrit, it is doubtful he could ever chant a single śloka in his life or was capable of conversing or writing a decent essay in the Sanskrit language. This raises the question of the credentials needed to usurp the title of Sanskrit scholar. What should be the minimum competency that one should demonstrate before one calls oneself a Sanskrit scholar? American Indologists have generally toed the line that Whitney first pursued and have not deviated from the Eurocentric, presumably because racial considerations predominated above all else. One wonders why in the face of such contempt for a people, these gentleman continued to study the heritage of the Indic people. The answer lies in their assumption that Sanskrit was not autochthonous to the subcontinent but was brought into India by the mythical Indo European or as they were known then by the name Āryans. They not only appropriated the Sanskrit heritage as their own but denied that it was native to the geography of the Indian subcontinent. This is a direct consequence of the loss of control by the Indics of their own historical narrative. No civilization or peoples can afford this luxury, if they wish to retain the authentic narrative of their own heritage See also Whitney (1874) and Whitney (1895)

[41] "John Bentley: Hindu Astronomy, republished by Shri Publ., Delhi 1990, p.xxvii;" By his [Playfair's] attempt to uphold the antiquity of Hindu books against absolute facts, he thereby supports all those horrid abuses and impositions found in them, under the pretended sanction of antiquity. Nay, his aim goes still deeper, for by the

G.R. Kaye, and Thibaut and continues on till today in the works of David Pingree. To quote Rouse Ball, historian of mathematics;[44]*The Arabs had considerable commerce with India, and a knowledge of* ***one or both of the two great Hindu works on algebra*** *that had been obtained in the Caliphate of Al-Mansur (754-775 CE) though it was not until fifty or seventy years later that attracted much attention. The algebra and arithmetic of the Arabs were largely founded on these treatises, and I therefore devote this section to the consideration of Hindu mathematics. The Hindus like the Chinese have pretended that they are the most ancient people on the face of the earth, and that to them all sciences owe their creation. But it is* ***probable*** *that these pretensions have no foundation; and in fact no science or useful art (except a rather fantastic architecture and sculpture) can be definitely traced back to the inhabitants of the Indian peninsula prior to the Aryan invasion****. This seems to have taken place at some time in the fifth century or in the sixth century when a tribe of Āryans entered India by the North West part of their country. Their descendants, wherever they have kept their blood pure, may still be recognized by their superiority over the races they originally conquered; but as is the case with the modern Europeans, they found the climate trying and gradually degenerated".***

We remind our readers that such a racist sentiment was expressed as late as the beginning of the 20th century, well after the renaissance and the enlightenment. It is also astonishing that he chose to advertise his lack of scholarship by asserting that there were only 2 great books in Mathematics. By doing so, surely he elevates his ignorance to a new level of hubris. It is quite clear that the only people claiming they invented everything are the Occidentals. To what purpose, by naming an age or era as an Enlightenment era, when the elite of this era do not show the slightest signs of such an enlightenment. Further this habit of the occidental of assuming he is enlightened enough to make this determination, lacks credibility in the absence of an independent authentication. As we have emphasized, there were exceptions such as Brennand, Playfair, Colebrooke, Sewell, and Bailly.

Even a scholar like James Prinsep feels constrained to remark that the real interest of the Occidental in matters Indic is generally aroused in those particular instances, (which I have highlighted in bold) where they have a more parochial interest. It is also interesting that Prinsep regards the historical narrative of India as largely legend when contrasted with Greece and Rome, which are rational. What makes the

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same means he endeavors to overturn the Mosaic account, and sap the very foundation of our religion: for if we are to believe in the antiquity of Hindu books, as he would wish us, then the Mosaic account is all a fable, or a fiction." So this is the argument that prevailed. Hindu astronomy could not be believed not because it was flawed, but that it would overturn the orthodoxy of the Christian church. So much for the scientific temper of western scholarship and their much vaunted blather about the importance that they attached to the scientific approach and the love of proof they inherited from the Greeks. In doing so, the Occidental chose to abandon all pretence of scholarship and with few exceptions preferred to succumb to his own prejudices.

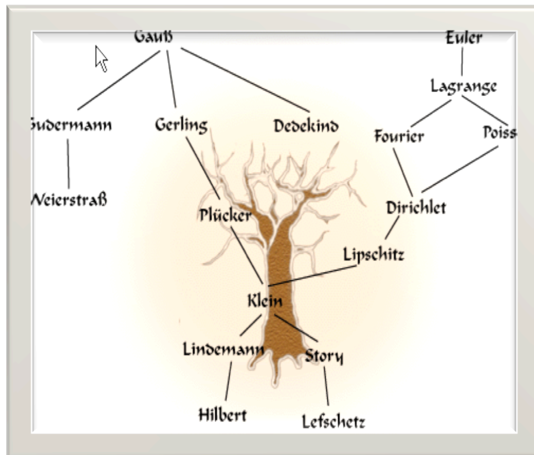
[42] *In 1925 The Professor of Indian Studies at the German University of Prague, Moriz Winternitz (1863-1937), denounced Schopenhauer for his admiration of the Upanishads with the following words - 'Yet I believe, it is a wild exaggeration when Schopenhauer says that the teaching of the Upanishads represents 'the fruit of the highest human knowledge and wisdom' and contains 'almost superhuman conceptions the originators of which can hardly be regarded as mere mortals...' On the subject of the Vedas, Winternitz had this to say -'It is true, the authors of these hymns rise but extremely seldom to the exalted flights and deep fervor of, say, religious poetry of the Hebrews.' Not even scholars seem to be immune to the quality of lack of graciousness when it comes to recognition of the work of other cultures and civilizations that seems to pervade the Occident.*

[43] *The famous German Indologist Albrecht Weber (1825-1901) was a notorious racist whose German nationalistic tendencies were thinly veiled as works on Indian philosophy and culture. When Humboldt lauded praise upon the Bhagavad-Gita, Weber became disgusted. His immediate response was to speculate that the Mahabharata and Gita were influenced by Christian theology -'The peculiar coloring of the Krishna sect, which pervades the whole book, is noteworthy: Christian legendary matter and other Western influences are unmistakably present...'*

[44] *W. W. Rouse Ball in 'A short account of the History of Mathematics' Dover Publications,1960, (originally appeared in 1908, page.146*

Indic historical narrative largely legendary and what makes the Greek History rational is not entirely clear. It is this kind of ad hoc characterization of the vast Indic literature, which leads one to conclude that the Occidental has no intention of studying the Indic contributions in a dispassionate, comprehensive, and thorough manner.

The initial flush of enthusiasm for the literature in Sanskrit in the eighteenth century is now a dim memory, and amongst astronomers and mathematicians, the fact that the Bernoullis[45] and Leonhard Euler[46] had knowledge of the Indic contributions and yet chose to ignore it, even earlier, is either forgotten or swept under the rug. This is of course assuming the current crop of philologists have the mathematical savoir-faire to understand these matters. When such a behavior is exhibited by famous savants like Euler and the Bernoulli's, it becomes increasingly easy to ignore the calls of conscience, and rationalize it in a variety of ways as a lacuna in the character of the Indic, until such a viewpoint becomes the norm.



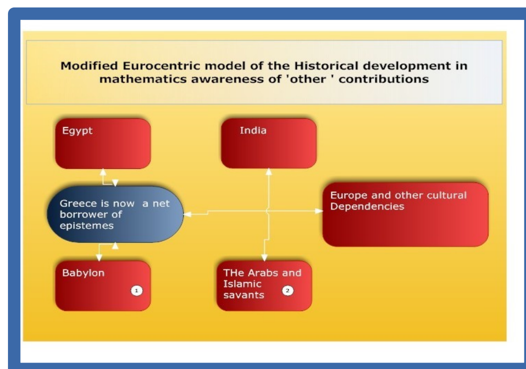
Leonhard Euler is one of the progenitors of the subsequent developments in Mathematics, which reached a level of maturity with David Hilbert. It is regrettable that Euler does not acknowledge his debt to Indic mathematics, even though he wrote a few papers on this topic, one of which was on the concept of Hindu tropical /sidereal year.

FIGURE 3 THE MATHEMATICAL GENEALOGY TREE

THE INTEREST IN GERMANY IN INDOLOGY

[45] Bernoulli, J., Description Historique et Géographique de l' Inde, Tome I, p. 5, Berlin, 1786. Tieffenthaler, J. Historisch-geographische Beschreibung von Hindustan. Aus dessen Latein. Handschrift übersetzt. Herausgegeben. Von J. Bernoulli. 2 Bde. Berlin und Gotha 1785—86; — Description historique et géographique de L'inde, qui présente en 3 volumes enrichis de 68 cartes et autres planches: i) La géographique de I'lndoustan, ecrite en latin, dans le pays même, par le père Joseph Tieffenthaler. 2) Des recherches historiques et chronologiques sur L'inde, et la description du cours du Gange et du Gagra, avec une très grande carte, par Anquetil du Perron. 3) La carte générale de L'inde, celles du cours du Brahma- poutre, et de la navigation intérieure du Bengale, avec des mémoires relatifs a ces cartes, publics en anglais, par Jacques Rennel. Le tout, augmente de remarques et d'autres additions, rédige et public en François, par Jean Bernoulli. 3 vols. 4° Berlin 1786 — 91.

[46] *Cited by CK Raju in 11– Euler's article was an appendix in TA Bayer's Historia Regni Graecorum Bactriani; GR Kaye Hindu astronomy, 1924, reprinted by Cosmo Publications, New Delhi, 1981, p.1. Euler is the culprit who named Pell's equation erroneously after Pell, after he had access to Indian texts and was clearly aware that Pell was not the progenitor of this topic.*


Modified Eurocentric model of the Historical development in mathematics awareness of 'other ' contributions
Egypt
India
Greece is now a net borrower of epistemes
Europe and other cultural Dependencies
Babylon
THe Arabs and Islamic savants

s long as the study of Indian antiquities confines itself to the illustration of Indian history, It must be confessed that it possesses little attraction for the general student who is apt to regard the labor expended on the disentanglement of perplexing and contradictory mazes of fiction as leading only to the substitution of vague and dry probabilities, for poetical, albeit extravagant fable. But the moment any name or event turns up in the course of such speculation, offering a point of connection between the legends of India and the rational histories of Greece and Rome—a collision between an Eastern and a Western hero—forthwith a speedy and a spreading interest is excited, which cannot be satisfied until the subject is thoroughly sifted by an examination of all the ancient works, Western and Eastern, that can throw concurrent light on the matter at issue.

Such was the engrossing interest which attended the identification of Sandrocottus with Chandragupta, in the days of Sir William Jones—such the ardor with which the Sanskrit was studied, and is still studied, by philologists at home, after it was discovered to bear an intimate relation to the classical language of Ancient Europe. Such more recently has been the curiosity excited on Mr. Turnour's throwing open the hitherto concealed page of Buddhist historians, to the development of Indian monuments and *Purāṇic records*."—James Prinsep. Late Secretary of the Asiatic Society.

In other words, this emphasizes what I wrote elsewhere when remarking on the interest that Germans have shown in Indological studies, that the *interest* of the Occidental in matters Indic, is primarily driven by curiosity regarding his own antecedents. *"In reality this field of study was dominated by German scholars. Interest in Indology only took shape and concrete direction after the British came to India, with the advent of the discovery of Sanskrit by Sir William Jones in the 1770's. Other names for Indology are Indic studies or Indian studies or South Asian studies. Almost from the beginning, the* Purāṇas *attracted attention from European scholars. But instead of trying to understand the* Purāṇas *and the context in which they were developed, the Occidental went about casting doubts on the authenticity of the texts, and in fact altering the chronology, which they could find in a particular* Purāṇa*. "*

The extraordinary level of interest by German scholars in matters Indic is a very interesting narrative in its own right and we need to reflect upon the highlights of this phenomenon. The German-speaking people experienced a vast increase in intellectual activity at about the same time that Britain colonized India. We do not understand the specific factors that came into play during this time, other than to remark on the tremendous intellectual ferment that was running concurrently during the French revolution, and the keen interest that Napoleon showed in matters scientific including the contributions of the orient. Clearly the remarks that Sir William made about Sanskrit as well as the high level of interest that he provoked in the Sanskrit language, contributed to the overall sense of excitement. But why was it Germany and not Britain, the center of research on the Oriental contributions. The answer lies in the intense search for nationhood that was under way in Germany during that period. When Sanskrit was discovered, and it dawned on the Germans that the antiquity of Sanskrit was very great, and that Sanskrit and German were somehow related, the Germans suddenly had an answer to the question of their own ethnic and linguistic origins. Sir Henry Maine an influential Anglo Indian scholar

and former Vice Chancellor of Calcutta university, who was also on the Viceroy's council, pronounced a view that many Englishman shared about the unification of Germany. "A NATION HAS BEEN BORN OUT OF SANSKRIT"

"From the beginning, the great interest that Germany showed in Sanskrit had more to do with their own obsessions and questions regarding their ethnic and linguistic origins. It had very little or at least far less to do with the origin of the ancient Indic, about whom they had considerably less interest. And yet, that does not stop the proponents of the AIT in India, whose knowledge of European history appears to be rudimentary at best, from asserting that AIT is primarily an obsession of nationalistic Hindus. Such is the fate and the perversion of history that conquered nations can aspire to."

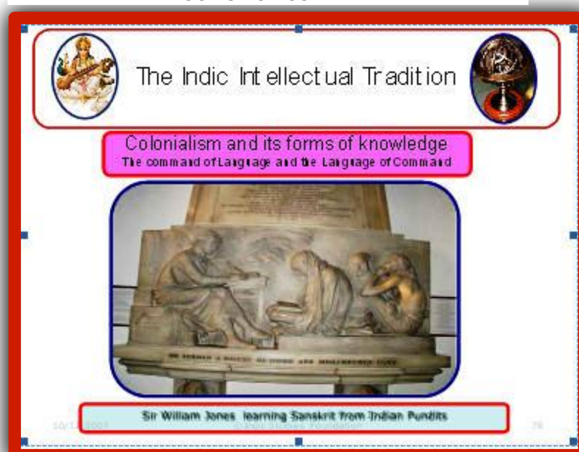
From the point of view of the Occidental, this is hardly surprising, and may not even be contested by him, but it is the propensity of the Indic, to grant these studies by the Occidental, uncritical approval and equal if not greater weightage, without sifting through the resulting distortions that they have introduced, that is unconscionable and does not bespeak the necessary due diligence that marks a scholarly approach to the topic and in the case of history, my contention is that the Indic has paid dearly for it. Sir William Jones made his famous quote on "the Sanskrit language, whatever be its antiquity, is of a wonderful structure; more perfect than the Greek, more copious than the Latin, and more exquisitely refined than either, yet bearing to both of them a stronger affinity, both in the roots of verbs and in the forms of grammar, than could possibly have been produced by accident; so strong, indeed, that no philologer could examine them all three, without believing them to have spring from some common source, which, perhaps, no longer exists". He made these comments while speaking to the Asiatic Society in Calcutta (now Kolkata) on February 2, 1786. Incidentally, while Sir William went on to say how much he loved Krishen and Arjun, the protagonists of the MBH War, that didn't stop him from barring Indics from becoming members of the Asiatic Society. In fact, the subcontinent of India was turned into a vast Gulag where no ideas were allowed to penetrate unless they had the sanction of the British. They then sequestered themselves in 'hermetically sealed cantonments' to minimize their contacts with the natives. The control of ideas and weaponry was the key with which the British controlled every aspect of life in the subcontinent. It is no wonder that the Americans emphasized the possession of weapons to such an extent, that they made it a part of the American constitution. Ironically, these adulatory words on the beauty of the Sanskrit language were literally the kiss of death for research into advanced studies in India. We need to remark on the astonishing reversal that took place, where the vaunted mastery of the Sanskrit language in the land of its origin was forever decimated in the scant space of 50 years after Sir William pronounced it to be a language more perfect than Greek, more copious than Latin. Fifty years later the first Sanskrit scholars from the occident started arriving in India to teach Indians the finer points of this language that was more exquisitely refined than either Greek or Latin and was spoken only in the Indian subcontinent. By promulgating Macaulay's minute on Education and making it a necessity for being gainfully employed; the British accomplished the goal of severing the umbilical cord that had tied the Indic Civilization to the Sanskrit Language for several millennia. At the same time while publicly excoriating the use of Sanskrit, they shipped vast amount of manuscripts to London and Oxford, and created the Boden Chair of Sanskrit in Oxford in order to ferret out the knowledge base of the Hindus. It was indeed a masterful stroke of public policy making, especially if the aim was to perpetuate British rule forever. Publicly denigrate the Indian classics as not worth the palm leaf they were written on, but privately encourage the study of Sanskrit, to the extent they would pay Max Müller 4 shillings a page for every page he translated of the Sacred Books of the East. Needless to say, that by the time he stopped working Max Müller was financially very well off. There is more than enough irony in the fact that he owed his livelihood to the poverty-stricken land of India, a state of affairs that his employer the East India Company had no small hand in creating. The transfer of wealth was massive and the Colonial Overlord was quite convinced that the loss of the Americas to the new colonies was more than recompensed by the conquest of India.

THE RELUCTANCE OF INDOLOGISTS IN THE OCCIDENT TO ACKNOWLEDGE THE VEDIC EPISTEME

As we have seen "*the problems in tracing origins back through time are many. First is the fact that great periods of time have a tendency to erase traces of cultures. When all traces decay then the culture is effectively obliterated. Whatever is left undestroyed by time becomes subjected to the cultural and personal opinions of archeologists. Such opinions may destroy and obliterate knowledge of the culture much more effectively than time ever could. Another problem is in the epistemology or method of knowledge used by countries foreign to the country or culture being studied. In the west we have a tradition of trying to understand life by studying corpses or trying to know health by studying disease. Archeology becomes an exercise of the imagination when trying to reconstruct a living culture based on remains of pot shards, bones, and bricks.*" [47]

The resulting paucity of knowledge and illiteracy on the part of the western scholar on matters pertaining to India was lethal to the understanding of their own history and leaves Occidental historians, the task of explaining why there was no progress in Europe between the time of the Greek contribution to the mathematical sciences and the flowering of the renaissance resulting in the Keplerian paradigm shift, a period exceeding 1600 years. All traces of their debt to any other ancient civilization have been systematically obliterated and a debt is rarely acknowledged (see a typical genealogical tree in Mathematics, Figure 2, Prologue) The current understanding in the Occident of the developments in Mathematics and Astronomy follow the flowchart indicated in Figure 5, where Figure 4 indicates the situation prevailing till recently. Note that India did not even appear as a contributor till about a hundred and fifty years ago. Needless to say our view of the matter indicates that the more current figure falls far short of reality by assigning the Indic contributions to the same chronological period as the Arabs and in many instances there is no mention of the Indic contribution at all.

FIGURE 6 THE COMMAND OF LANGUAGE AND THE LANGUAGE OF COMMAND



David Pingree had a great deal of difficulty, even conceding that the Indics started using the circle as part of the decimal place value system, until the Greeks brought this concept with them from Babylon to India. He asserts with great certainty that " the Greeks appeared in India **in large numbers bringing with them among other things, astronomical tables in which in the sexagesimal functions, the empty places were occupied by a circular symbol for zero, such as are found in the Greek papyri of that period".**[48] Surely if they were in such large numbers and he is sure of his facts he should be able to rattle of their names in rapid succession. One

[47] *http://web.nickshanks.com/history/sixthousandyears/*

[48] *Pingree, David, "Zero and the Symbol for Zero in Early Sexagesimal and Decimal Place Value Systems" in "The Concept of Śūnya" a collection of essays edited by AK Bag and S R Sarma, published by the Indira Gandhi International Centre for the arts, INSA, Āryan Books international, 2003*

should rightly be critical of those who claim to foretell the future but what of those who are able to peer into the distant past and are able to see all the details of the above scene down to the minutia without any evidence whatsoever. All I can say is, would that we were all so blessed. I say it is time for the Indic to stop humoring such excursions into fantasyland using the excuse that it would appear unseemly to question events that have been misrepresented for a long period of time. We discuss Pingree's pronouncements on Indic contributions in chapter IX where we discuss the subject of transmission of knowledge, in much greater detail, including many Case studies, which consistently bear out our view of the matter.

We have used these flowcharts from the work of previous scholars who have studied these developments. We are compelled to remark that the sudden explosion of knowledge that took place during the renaissance occurred shortly after the Jesuits sent 70 scholars to Malabar in the 1500's. When it came to reconciling himself with the obvious depth of knowledge of the ancient Indic, the occidental had no hesitation in coming to the conclusion that the Indic had borrowed everything from Greece. But he is more than reluctant to accept that a massive transfer of knowledge took place from India to Europe during the 16th century, even though the evidence is far more compelling. In fact all evidence pointing to such a transfer is completely ignored. We will remark in passing that there is a palpable difference in the manner in which the Occidental views the transmittal of knowledge, depending on the direction in which the transmittal is alleged to have transpired.

THE OBSESSION OF THE OCCIDENTAL WITH CHRONOLOGY AND TEMPORAL PRIORITY

Elsewhere we have documented the shoddy manner in which the Occidental (in this instance Sir William) had falsely interpreted a Greek synchronism[49] and had lopped of 1200 years of the history of India. The Occidental has often accused the Indic of claiming a high antiquity. But surely this is a non *sequitur*, because if the ancient Indic was in fact obsessed with, and explicit about dates, this situation where the Occident could introduce an element of uncertainty, and doubt would not have arisen. It is because of the allegedly cavalier and nonchalant treatment of chronology in the Purāṇic accounts that gave the opening for the Occidental to claim that the Indics does not have sense of historical agency. Surely we would be forgiven if we asked ourselves the following question. What was it that motivated the Indologists to be so emphatic about the alleged lack of historiography amongst the ancient Indics? Was it motivated by a scientific quest to discover the true history of India or was it really meant to debunk the antiquity of India

In reality the chronicles of the ancients are voluminous and there is more than a minimal amount of redundancy, so much so that, contrary to the notion of inadequate historical data we are faced with an embarrass de choix and not one of dearth of data. It is time the Occidental makes a choice, was the Indic nonchalant and indifferent about chronology, or was he obsessed with having a high antiquity. Both of these charges cannot be right simultaneously.

When Sir William made the colossally erroneous determination that Megasthenes was an Ambassador to the court of Chandragupta Maurya, it is doubtful whether he was aware that there was another

[49] *Kosla Vepa, http://www.scribd.com/doc/12314897/The-Pernicious-Effects-of-the-Misinterpreted-Greek-Synchronism-in-Ancient-Indian-History Paper presented at the ICIH 2009 India International Centre, January 9-11,2009, also available as part of the Souvenir Volume of the conference*

Chandragupta of the Gupta Empire. Certainly he makes no mention of the later Chandragupta during the ensuing months before he died. A wave of jubilation swept through the handful of European Indologists when they heard that India did not have the antiquity, which they were originally led to believe. They rejoiced that in fact the Indian claim to hoary antiquity for their history was bogus. The Purāṇas, they declared, were not reliable. They are the works of wily Brāhmaṇas. How could a conquered nation aspire to an antiquity beyond October 23, 4004 BCE? They conveniently swept under the rug the glaring fact that the Purāṇas were written many centuries before their arrival in India and that their compilers had no reason to distort the history and neither did they have to convince anybody of their antiquity, a point that Pargiter makes on more than one occasion in his book on Ancient Indian Traditions. Little did they realize that there would come a time when the events that they described would be questioned so vociferously? It is not even clear whether the ancients considered antiquity to be a desirable characteristic, and that it would in time be questioned by a group of people whose sole concern was to shorten the antiquity of India. Why do we mention these facts here in the context of the calendar? Because the resulting shortening of the time line had several serious effects on the dating of the important texts such as the Vedanga Jyotisa. The occidental was not merely content to excommunicate the Indic from his own heritage but decided to appropriate this heritage as his own and went on to propound his own theory as to the origin of the ancient tradition of the Indic people. He proposed that Sanskrit could not have been developed by the natives of the subcontinent, clearly implying that they did not have the intellectual capacity to do so, but was grafted on to India by a band of marauding Central Asian nomads; the only restriction that was put on the origin of these Āryans was that they hailed from a place that was anywhere but from India. This was the first and most significant finding from the new field of Indology, a topic that had a lot of similarities to Entomology, the study of insects, the most significant similarity being that the subjects of the study had little say in the matter and were more than likely expendable in the process.

DIFFERING STANDARDS OF CLAIMS FOR TRANSMISSION OF KNOWLEDGE

We would be remiss if we did not make the observation that the direction in which knowledge was transmitted had a profound impact on the perception of whether there was any transmission at all. Many have been the individuals from other parts of the world who studied at Indian universities like Nalanda, Takśaṣīla, Vikramṣīla, and Odāntipura till the 12th century. It was a rare instance where they would go back and denigrate the knowledge they had so acquired or the land they acquired it from, and in fact went out of their way to eulogize the education they received at these locations which were studded all along the Gangetic valley, but particularly so in Vihara (Bihar). However all this changed during the 16th century when the Society of Jesus (Jesuits) sent highly educated (for those days) individuals, the number sometimes exceeding 70 or 80 at times at any given point in time, whose sole purpose was to extract as much information from the people who practiced such skills, like Jyotish Pandits and engage in intellectual property theft. What defines such activity as theft? If the recipient does not acknowledge the source of his teaching then it is fair to call it theft. There is another oddity, in the obsession that Occidentals have, with their insistence that India borrowed everything from Greece. They cannot point to a single instance of any individual either Greek or Indian who is credited with the transmission. The only fact they refer to is the significant presence of Greeks left behind in Bactria after the invasion of Alexander, who survived till about a hundred years prior to the Common Era. The claim is usually made that there were several Greek emissaries who could have transmitted this knowledge. But such emissaries are rarely endowed with scientific knowledge, and to expect Alexander or any of his generals to sit down and patiently teach the Indics the intricacies of Greek astronomy is certainly not a realistic scenario, given also that the state of astronomical knowledge in Greece prior to

the advent of Ptolemy was moribund. We maintain that in order for transmission to have taken place, either of 2 mechanisms must have been present:

1. Indic scholars went to Alexandria after it was founded, returned, and taught it to others at one of the famed universities of India. While this is entirely possible, it is astonishing that the name/or names of such a learned person would not be available to us. The absence of such an individual in the historical record leads one to believe that this did not happen. There are names of Indics who went to Greece but as far as I am aware we do not have the names of any Indic who returned. It is inconceivable that the author of a major text, during the time period in question, would not have left behind references to his work and association with the Greeks. The contrast with China is illuminating in that we have the names of more than one Indian and Chinese individual who went back and forth from China and India.
2. Greek astronomers came and taught at one of the famous universities of India (Nalanda, Odāntipura, Takśaṣīla, and Vikramṣīla).

Furthermore a necessary condition for the transmission from Greece to India to have taken place is that the Greeks must have discovered the content at least decades before the Indians did (and probably earlier) in order to be able to record and disseminate the knowledge in Greece prior to transmitting the knowledge to India. The currently accepted chronology of India and Greece precludes such a possibility, since most of the developments in Greece took place after 600 BCE, while the date of the Vedāṅga Jyotiṣa is estimated to be between 1860 BCE TO 1300 BCE. We are confident that by the time we come to 1300 BCE the Indics had accumulated a vast body of knowledge about the solar system and had established their general approach to solving the problems of calendrical astronomy. The question of transmitting Greek science to India is a non-starter. And yet, the Occidental insists with a numbing regularity that it took place. In fact no study of this kind would be complete without a reference to the differing standards by which Occidentals have concluded whether a particular discipline was imported or exported out of the Occident. We quote C K Raju[50]in his monumental work on the philosophical and historical underpinnings of the mathematical sciences. (Page 314).

"*However, we have also seen that the standard of evidence is not uniform, but varies with the claim being made. The standard of evidence required for an acceptable claim of transmission of knowledge from East to West, is different from the standards of evidence required for a similar claim of transmission of knowledge from West to East. Thus there is always the possibility that similar things could have been discovered independently, and that western historians are still arguing about this, even in so obvious a case as that of Copernicus. Finally we have seen that this racist double standard of evidence is not an incidental error, but is backed by centuries of racist tradition, religious exhortations by Popes, and by legal interpretations authoritatively handed down by, say the US Supreme Court."*

Priority and the possibility of contact always establish a socially acceptable case for transmission from West to East, but priority and definite contact never seems to establish an

[50] C K Raju "Cultural Foundations of Mathematics", Centre for Studies in Civilizations (PHISPC), Pearson Education, 2007, page 313. It is my opinion that this is a landmark publication on the Civilizational uniqueness of the Indic contributions, juxtaposed with the philosophy of the history of science. It should be read in entirety by every educated person interested in these matters and particularly by the Indic population

acceptable case for transmission from East to West, for there is always the possibility, that similar things could have been discovered independently.
"Hence to establish transmission we propose to adopt a legal standard of evidence, good enough to hang a person for murder. Briefly we propose that the case for any transmission must be established on the grounds of
1. Motivation,
2. Opportunity,
3. Circumstantial evidence (the circumstantial trail of evidence has been documented in detail by CK Raju and has been tabulated in Table 7.1 on page 453 of CFM)
4. Documentary evidence.
The importance of epistemological continuity has been repeatedly stressed above by Raju; any such claim, he emphasizes, must also take into account Epistemological; Issues.

***EPISTEMOLOGICAL ISSUES**.*

The cognitive dissonance resulting from incomplete understanding of epistemological issues and maintaining epistemological continuity is almost a certain indicator that the technology has been plagiarized from elsewhere. Examples abound, especially when it comes to areas such as Mathematics, Astronomy and Linguistics and the discovery of the origin of scripts. In particular we cite the instance of David Pingree's PhD thesis titled "Materials for the Transmission of Greek astrology to India". (His thesis advisers were ON and Daniel Ingalls). Notice, he does not ask whether such a transmittal ever happened. That is a given, a hypothesis that need not be proven. This is another example of a circular argument. Assume the answer that there was a transmittal, in the initial hypotheses, merely because there was probable contact however, tenuous though it may be, and then claim that it is an incontrovertible fact. We will discuss in detail a couple of cases in chapter IX where the elite historians of the west have dogmatically (and erroneously) maintained that the Greek influence on India dominated Indic thought.

The conventional wisdom in the West was that the Jesuits were sent to convert the Indics to the Christian faith and as a byproduct teach them the finer points of the occidental civilization. In reality it turns out, they were sent to learn a whole host of topics such as navigation, mathematical techniques including trigonometry, and the Indian approach to calendrical astronomy by Christopher Clavius, the Director of the Collegio Romano. The list of names in this roster included Matteo Ricci[124], who went on to spend a considerable time in China, but not before he spent 5 years in Malabar learning from the Namboodri Jyotiṣa Pundits. In short, the Jesuits embarked on a systematic study of the Indic episteme, since it was obvious that the Indics had made considerable advances, which the Jesuits were quick to realize were far in advance of their own. We are in the process of chronicling the study of those individuals who in turn studied India or studied subjects in which the Indics had great proficiency, beginning with ancient Babylon to the British, primarily to understand the role that India and the Indic episteme played in the renaissance of Europe. While there is nothing here that can be regarded as being morally reprehensible, one wonders why there was the extreme reluctance to admit that they learned from others too. In this, one has to concede that the Arab scholar during the heyday of Islam observed a higher degree of ethics than his brethren in the Occident, because he never exhibited the slightest hesitation in attributing to the Indic the episteme that he had learned from him.

Typical of the stance of the Occidental is the attitude of the late Professor David Pingree who occupied

the only faculty position that I am aware of, on the History of mathematics in the western world at Brown University. On the one hand, Professor Pingree, spent most of his entire professional career studying Indian texts and manuscripts. He compiled and catalogued a comprehensive bibliography of all materials available on the computational sciences in India. The work was so voluminous, that the net result was a 5 volume compendium which he aptly termed the Census of the Exact Sciences in Sanskrit (CESS)[51], cataloging a massive amount of literary work[52] that could never be replicated from what we know today to be the corresponding output from Greece. Yet he kept insisting that India lacked the astronomical tradition necessary for the development of these techniques.[53] Typical of his statements is one where he remarks that 'both the Brahma Pakṣa and the Ārya Pakṣa schools of Astronomy, seem to have antecedents in Greek astronomy'.[54]He is unable to assert with any modicum of evidence that such a transmission happened. Yet he keeps insisting that it did.

FIGURE 7 JOSEPHUS JUSTUS SCALIGER



As CK Raju has shown, the work of the Greeks suffers from the basic difficulty that prior to Ptolemy there exist very few records of their work. It is now recognized that Euclid may have been a fictional character[55,56]. There are good reasons to assume that he in fact never existed and may have been manufactured by the Vatican to avoid giving the credit to the Arabs for the Geometry that they had mastered or possibly having to admit that the Theonine text which is usually referred to as the Elements of Euclid was partially coauthored by Theon's daughter Hypatea, who was flayed alive at the behest of the church. The main claim of the Occidental to have any kind of priority over the orient in matters mathematic, rests therefore on texts that did not even exist till well after the commencement of the Common Era. Given these realities it

[51] David Pingree, Census of the exact Sciences in India , Series A, in 5 Volumes, American Philosophical Society, Independence Square, Philadelphia, Under a grant of the National Endowment of the Humanities, 1994

[52] To give an idea as to the quantity of literature in the CESS, there are 26 pages of citations on Bhāskara II alone, CESS, Series A, Volume 4, pp.299-326.Note the census is organized alphabetically by author (according to the Devanāgari alphabet)

[53] David Pingree 'The recovery of early Greek Astronomy from India", JHA, vol. vii (1976), pp.109-123.

"However, one of those civilizations that was profoundly influenced by Greek culture has preserved a number of texts (composed in the second through seventh centuries CE) that represent non-Ptolemaic Greek astronomy. This civilization is that of India, and the texts are in Sanskrit It is certain that Greek astronomical texts were translated into Syriac and into Pahlavi, as well as into Sanskrit, but of the former we still have but little, and of the latter almost nothing; and in both cases we must rely for much of our knowledge on late accounts in Arabic. The Sanskrit texts, however, though often either incorrectly or not at all understood by those who have transmitted them to us, formed the basis of a scientific tradition that only in this century has been destroyed under the impact of Western astronomy".p.109

"These techniques as preserved in the Sanskrit texts were certainly not invented in India, which lacked the astronomical tradition necessary for their development. Nor were they introduced directly from Mesopotamia since they first appear, in a crude form, in the Yavanajātaka, which is based on the translation of a Greek text made three-quarters of a century after the last dated cuneiform ephemerides was inscribed."p.111

[54] David Pingree 'Bija corrections in Indian astronomy' JHA, vol. xxvii, (1996), pp.161-172

[55] C K Raju, ibid

[56] Constance Reid 'A long way from Euclid', New York, 1963 "We have no copy of the original work. Oddly enough we have no copies made even within one or two centuries of Euclid's time (circa 200 BCE). Until recently, the earliest known version of the Elements was a revision with textual changes and some additions by Theon of Alexandria in the 4th century CE, a good 6 centuries after the nonexistent Euclid purportedly compiled it in Alexandria. The traditional text book version of the Elements almost completely until very recently without change was based, of course on the text of Theon. …. when we say Euclid says. we are speaking of a compiler much closer to us than the original compiler of the Elements"

makes no sense to talk about Euclid as an individual, but as a process culminating with Theon of Alexandria.

Record keeping in Greece did not have the benefit of an Ahargaṇa (or its later day adaptation the Julian day number). The Julian Day Count has nothing to do with the Julian calendar introduced by Julius Caesar. It is named for Julius Scaliger, the father of Josephus Justus Scaliger, who is credited with enunciating the concept in 1582 CE. It can also be thought of as a logical follow-on to the old Egyptian civil calendar, which also used years of constant lengths. In fact the circumstantial evidence points to the adoption of this number by the Occident after the Principal of the Collegio Romano sent a posse of 60 to 70 Jesuits to Malabar circa 1560 CE with the express purpose of ferreting out the knowledge base of the Hindu. It was shortly after this that the reform of the Julian calendar was instituted by the Vatican and the Julian Day number appears to be a natural outcome of the knowledge gained by the Jesuits and is in fact a direct adaptation of the Ahargaṇa.

FIGURE 8 THE COPERNICAN MODEL



Greeks used to measure their eras based on the current Archon of Athens (I am indebted to the late Dr Murali Dhar Pahoja for pointing me towards this revelation) and their entire chronology is largely suspect. This may have been because of the fear of large numbers that seemed to have pervaded the Occident in the ancient era, which also explains why they had no symbols or numbers larger than a thousand. Most Indians have been persuaded by the Colonial power into believing that Indian chronology is faulty and wanting (compared to whom?). Such an assumption is belied by the fact that it is the Indian records that they depended on to decipher what the Greeks did according to David Pingree. We will illustrate the inherent contradictions in their stance towards Indian historical record keeping in the chapter on knowledge transmission, where we examine a half a dozen instances of similar contradictions. (See Chapter IX).

Typical of such pronouncements is that of MacDonell "*To the various excesses and grotesqueries that arise from defects of the Indian mind*"[57], according to A. A. MacDonell, is to be added the non-existence of history. ''*The total lack of the historical sense is so characteristic, that the whole course of Sanskrit literature is darkened by the shadow of this defect …Early India wrote no history because it never made any*''[58]. Along the same vein is the comment by A B Keith "… *despite the abundance of its literature, history is so miserably misrepresented … that in the whole of the great period of Sanskrit literature, there is not one writer that can seriously be regarded as a serious historian*". It is now clear that these statements were made to create a doubt in the minds of the reader regarding the adequacy of the historical accounts of India in order to pave the way for the Occidental to accept the revisions of the history that he (the colonial overlord) had concocted. The utter absurdity (I am being charitable in my characterization, where no charity is warranted) of these statements lies in the fact that eminent scholars like Colebrooke, Sewell, Max Müller, Albrecht Weber, Jean Filliozat, Moriz Winternitz, Ebenezer Burgess, Frederick Pargiter, Whitney, Hermann Jacobi, John Playfair, GR Kaye, Keith, and many others

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[57] *We might be forgiven if we indulged in the rejoinder, that one of the defects of the British mind has been the propensity to pass judgment on the Indic civilization, knowing full well that the Indic was in no position to defend himself*

[58] *MacDonell, 1900, p.11*

spent their entire lifetime studying the non-existent history and literature of India. Robert Sewell, who did a lot of work in deciphering the Indian Calendar, also wrote a book on the Vijayanagar Empire, called the Forgotten Empire, presumably because he was afraid that the British policy of downgrading the Indian past, as one with no history, would also result in the overlooking of the Vijayanagar empire, which in fact lasted a longer period than the Mughal Empire. While one cannot escape the conclusion that envy played a large part in such judgments, there are several reasons why such statements should be considered suspect and lacking in objectivity;

1. The presumption that the Occidentalist makes that he has seen all the literature there is to see. There is considerable hubris in such an assertion primarily because the manuscript wealth is so staggering, amounting to over 5 million manuscripts, out of which only a million have been catalogued and the number that have been read and translated is far less[59].
2. The statement is patently untrue because there are several treatises that qualify as itihàsa.
3. It is possible that the ancient history of India does not follow the requirements that modern historians place on it, but this merely tells us that the history of an ancient people should not be expected to meet retrospective ISO 9000 like criteria and should be judged by the criteria that the ancients have set themselves.
4. I marvel at the certainty with which the Occidental pronounces that India has no history without at the same time conceding the possibility that ignorance of the subject matter on their own part, does not equate to evidence of absence.
5. The real comparison that should be made is with histories of other civilizations during comparable era. For instance any comparison of the Vedic historical period should be made with histories of other civilizations during the period 7000 BCE to 4000 BCE.
6. Referring to a sheet anchor they used the Ahargaṇa (□□□□□ण) to get a serial day count starting with the sheet anchor. The Greeks never made that extra step and even if they realized the need to do so did not have a name for a number larger than a thousand. In fact it would not be out of place to study the Shahnama of Firdausi to understand the basic structure of Greek history and contributions.

In reality the Indians were the first to realize that there is value in astronomy. By any reasonable standard the Greeks would flunk the minimum requirement for accurate record keeping. But by perverse logic it is India that is saddled with the onus of proving it has a legitimate history.

There is very little remaining of the work of Hipparchus or Aristarchus. Even Ptolemy's Syntaxis is actually a translation of the Arabic Al Majisti. **Baṭlaymūs Al Qualuzi** (Roman Name Claudius Ptolemy) who is supposed to have lived in Alexandria during the reign of the Ptolemy's called his work the Η Μεγαλη Συνταχιξ (Megali Syntaxis) τηξ Αστρονομιαξ, Great System of Astronomy. It was translated by Al Thābit ibn Qurra at about the time of the Khilafat of al Ma'amun (circa CE 850, see for instance Saliba[60]) and the name of the translation was Al Kitāb al Majisti, the Greatest Book. In the early years after the translation into Latin from the Arabic, even as late as 1515 it was known as the Arabo-Latin translation and was the only book on astronomy available to the Europeans for several centuries. It was clearly an accreted work (see the extensive discussion by CK Raju[61]) reflecting the knowledge gained by the Arabs at the House of Wisdom, The Bayt al Hikmah. The Al Majisti was a completely revamped text by the time it reached the library at Toledo in the 11th century. It had profited immensely from the great **Entrepôt** that the Bayt al Hikmah became with inputs from Persia, India, Khorasan, and

59 Goswami, B N., Ed., The word is Sacred , Sacred is the word, The Indian Manuscript tradition, National Mission for Manuscripts, ISBN 81-89738-22-4,January 2007
60 Saliba, George, 1994,' A history of Arabic Astronomy', New York University Press, New York, NY
61 CK Raju, ibid, PP.197

Alexandria. The direct translation from Greek was available only in the 16th century, from a Vatican manuscript. One wonders why the Vatican took 18 centuries to find this manuscript.

Given that Europe used the Arabic version (translated into Latin) for several hundred years, I do not see how the Occident is so certain that Indians borrowed from Greece. But like the Village Schoolmaster (by Oliver Goldsmith), David Pingree the Guru to those who currently maintain such a stance, never gave up his obsession with Greek Priority and "even though vanquished he could argue still". His students (chelas) continue to spread this version with very little proof of their assertions. In most cases, the Occidental has resorted to what is known as 'Speculative Reconstruction' in order to bolster his contention that the Indic has borrowed from the Occident. This is the fig leaf that he uses, since he has no other proof that the Greeks had anything to offer, in order that he establishes priority. Unfortunately the present day successors of the Knights of the Round Table have forgotten the meaning of honor and graciousness. They will stoop to any level to maintain the supposed superiority of the Occident over the Indic. This obsession of claiming an ancestor who is supposed to have invented everything under the Sun is a serious social pathology that the occidental should face up to with the very real danger that he may lose all credibility if he does not cease from such endeavors.

In a powerful talk drawing upon the rich epistemological tradition of the ancient texts, the Chairman of the ICIH 2009 conference held in Delhi during January 2009, Prof Shivaji Singh[62] demolished the notion originally enunciated by Hegel and others such as Karl Marx that the Indic civilization lacked Historical agency. That such an attitude was self-serving and provided a rationale for retaining control of a vast geography of the planet, an attitude that Jawaharlal Nehru felt compelled to address, even though in a more oblique fashion, in his Discovery of India, is all the more obvious. Despite this, a substantial portion of Indian historians feel obligated to perpetuate this cliché, which originated out of a lack of knowledge and understanding of the vast literature of India on the part of the Occidental, simply for no other reason than the Occidental origin of this assertion.

This goes merely to show that the Indic should free himself of the assumptions that his Occidental counterpart unconsciously makes when writing about the History of India and should not rely on his conclusions. Rather he should focus on the validity of the assumptions that the Occidental makes explicitly and implicitly while reaching his own categorical assertions.

We view the study of history and philosophy of science as central to the understanding of any civilization and its ethos. We were pleased to discover that Neugebauer[28] made a similar statement regarding the utility of studying history of the mathematical sciences; hence we make no apology for the emphasis on science, and especially on Astronomy in our own studies of the Indic peoples. Such an emphasis has been lacking in the past partly because major advances in the sciences, that have the potential to be of use in the study of history, have occurred only recently in the last 100 years and partly also because it has been difficult to find individuals who have proficiency in more than one discipline, such as Astronomy and Archaeology. It is our expectation that Archeo Astronomy will become a field of study on its own right and ameliorate this situation to some extent, but the larger question remains as to why till hitherto, there have been so few studies of the Mathematical traditions of the Indic peoples, interwoven into the general studies of history of the subcontinent and into the history of each of these sciences.

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[62] Prof Shivaji Singh "Contending Paradigms OF Indian History; Did India lack Historical agency, published in Souvenir Volume of ICIH2009.

FIGURE 9 CONCENTRIC MODEL

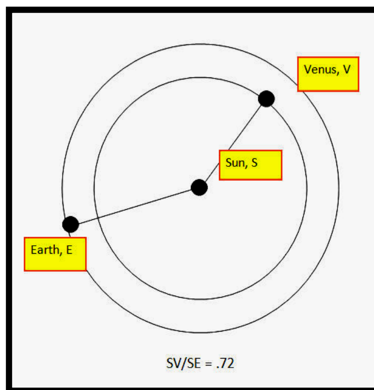
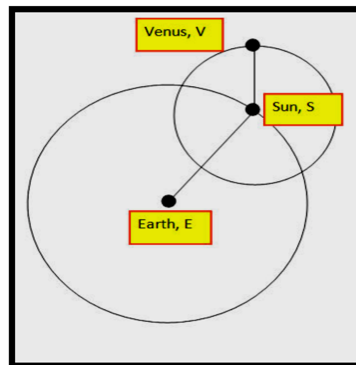


FIGURE 10 ECCENTRIC/EPICYCLIC MODEL



TRIC PARADIGMS

A word is therefore in order about the manner in which we construct the models of the universe. It is only in the last 500 years, or even less, that we have shifted unambiguously to a heliocentric view of our Solar system. This step was a major paradigm shift for the human species. But this does not mean that the geocentric models that were constructed in the past were wrong or that the models were an obstacle to further progress. Nor does it mean that the ideas leading inexorably to a heliocentric model, such as the realization that the earth rotates about its own axis , did not occur to those who were capable enough to visualize the consequences (Āryabhaṭa and Aristarchus come to mind). It simply means that the species had not evolved to the point where it could appreciate the consequences of the heliocentric model.

From time immemorial, humans have been watching the periodical rising and setting of the objects in the sky including the Sun, the Moon, and the planets. One cannot help but ask the question, 'why is this happening?', and how they collected the data and when they come up with the computational algorithms that were needed to determine the positions (declination, right ascension) of the various heavenly bodies. There are more questions rather than real answers.

However, the ancients made several observations that can be forensically examined in order to arrive at the truth.

GEOCENTRIC AND HELIOCENTRIC MODELS OF THE SOLAR SYSTEM

The Earth spins around its axis once a day and thereby causes the apparent motion of all the objects surrounding us. This leads us eventually to the heliocentric model. This was first hypothesized by AB. The Occidental claims that Aristarchus also hypothesized the rotation of the earth.

The entire celestial sphere with all the objects in it rotates once a day while the earth alone is stationary. In this model at least in the case of the inferior planets (see Glo-pedia) Venus and Mercury, the Sun is orbiting around the Earth. This can be termed cycle 1, and there is a second cycle, where the inferior planet is orbiting the Sun. This we shall call cycle 2, and is known as the Epicycle. In western literature cycle 1 is known as the Deferent in the case of the inferior planets. To a first order, the 2 models are similar and can be shown to be vectorially equivalent for the case of zero Eccentricity. A coordinate system that is geocentric is extremely useful for describing the map of the sky, if for no other reason than, that it is the way we see the universe around us. Still, it is pertinent to remind ourselves that the planet earth is only one of the planets of the Sun, which is an insignificant star (among billions of others) in one of the spiraling arms of the Milky Way Galaxy, which in turn is one of millions of Galaxies.

TABLE 2 ĀRYABHAṬA ON RELATIVE MOTION
anulomagatiḥ nausthaḥ paśyati achalam vilomagam yadvat |
acalāni bhāni tadvat samapaΓścimagāni laṅkāyām || 9 ||
Golapādah, 4.9 of Āryabhaṭīya
अनुलोॅमगतिर्नौस्थः पश्यत्यचलं विलोॅमगं यद्वत् ।
अछलानि भानि तद्वत् समपश्चिमगानि लङ्कायाम् ।।
udayāstaMāyanimittam nityam pravaheṇa vāyunā kṣiptaḥ |
laṅkāsamapaśchimagaḥ bhapañjaraḥ sagrahaḥ bhramati || 10 ||
Golapādah, Chapter 4.10 of Āryabhaṭīya **उदयास्तमयनिमित्तं नित्यं प्रवहेॅण वायुना क्षिप्तः ।**
लङ्कासमपश्चिमगः भपञ्जरः सग्रहो भ्रमति ॥ १० ॥

The sheer vastness of the universe in which the planet earth is an insignificant tiny spec, should be a deterrent to taking ourselves too seriously, much less kill each other for some imagined slight or grievance. It is the consequence of the heliocentric system that forces us to re-examine our role and purpose in the Shiva Tandava that is a quintessential metaphor for the vast cosmic drama that we are so privileged to be a part of. Āryabhaṭa makes mention of the rotation of the earth about its own axis[63], {Sloka 9,and since such a rotation would explain the apparent movement of the planets and other objects in the sky, he was tantalizingly close to an explicit statement regarding the heliocentric nature of our Solar system.

Just as a person in a boat moving forward sees the stationary objects (on the river bank) as moving backwards, the stationary stars are seen in Lanka (at the equator) as moving towards the west.

But it was not to be. It would be stretching the truth to say that as far as we can fathom, he had a clear idea regarding heliocentricity. In the interest of full disclosure we need to mention that in the very next verse he repudiates the heliocentric model[64], indicating that he had not reached a final conclusion or that he was unable to reconcile the competing viewpoints. The rising and setting (of all the celestial objects) being blown by the Pravaha wind, presumes the movement of the stellar sphere along with the planets at a uniform rate.

Thus, we see no evidence that the Indic ancients ever hypothesized a heliocentric model. The opposition that was expressed by Brahmagupta to the proto-heliocentric model, namely the key finding of AB, that the earth which was rotating around the sun, was due to his inability to explain the phenomena based on the heliocentric model and not due to any religious orthodoxy.

In fact I can safely say that I know of no instance in Indian history where religious orthodoxy ever had a decisive say, much less a veto power on matters relating to science. This is in stark contrast to Europe where the church had total control of the dissemination of knowledge resulting in the stagnant state of affairs till almost the 20th century when **Laplace** is reported to have replied to Napoleon 'Sire***, Je n'ai pas***

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[63] *Āryabhaţīyam, Golapādah, Chapter 4,9, Āryabhaţa*
[64] *Ibid, Chapter 4, 10*

besoin de cette hypothèse' when asked why he hadn't mentioned God in his discourse on secular variations of the orbits of Saturn and Jupiter.. . This conversation was reported to have taken place after Laplace had presented a copy of his work to the brilliant Emperor, who undoubtedly did more than his share for encouraging the scientific revolution that was under way in Europe. When Napoleon repeated this to Lagrange, the later remarked. "***Ah but that is a fine hypothesis, it explains so many things.***

As I have emphasized, humanity was not ready till that time, to begin the long March to unshackling itself from the self-imposed mental Gulag of dogmatic thought processes as well as the realization of the potential to free us from the cocoon of the Solar system.

The idea of a heliocentric planetary model did not 'catch fire' and did not cause a paradigm shift in the manner in which people viewed themselves either in a terrestrial frame or otherwise. Without the accompanying revolution of thought, such a statement is without impact and hence is of little significance from the point of view of further progress. After all, Aristarchus is reputed to have postulated a heliocentric system as well and the same remark applies to him also. But the idea did not die in India (and I am sure elsewhere) and it fell to the hands of people like al-Shatir(d 1374) and Urbi (d. 1268) at the El Maragha observatory and Nīlakaṇṭa of the Kerala school(1443 to 1543 CE) to appreciate the significance of this statement.

By contrast, the Copernican revolution was a major event in the history of the human species and caused a veritable explosion in the sciences. Again as in the case of Analysis and the Calculus, we agree with Richard Courant that it makes little sense to say that one individual was responsible for the evolution to a heliocentric model. We are confident that the Indic contribution will be recognized as a significant portion of the total effort, not just for the efforts of savants like Āryabhaṭa but also because it contributed to the Copernican revolution in more ways than the occident cares to admit[65]. Certainly the Ancient Indic deserves better than to be completely ignored in any narratives of the history of Astronomy[66,67,68].

We wish to make it clear that unlike the Occidental we are not trying to establish priority in every field that the Indic may have made contributions, but it also does not make sense to ignore the contributions of the Indics merely because they fell prey to the colonialist urge to plunder and lost control of their own history and should pay for this lapse for all time by never correcting the historical narrative. But even this limited recognition of the work done by the ancient astronomers of India is currently absent and there remain compelling reasons to assume that the Occident will remain reluctant to grant even this limited recognition. Why, because, he is concerned that the whole edifice of lies and half-truths will

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[65] Nilakanta's contributions to the progress towards a heliocentric paradigm as elaborated by Ramasubramanian in Ramasubramanian, K., Srinivas, M.D. and Sriram, M.S., Modification of the earlier Indian Planetary theory by the Kerala Astronomers and the implied heliocentric picture of planetary motion, Current Science, 66, pp. 784-790. May 1994.

[66] Evans, James, "the History and Practice of Ancient Astronomy", Oxford University press, 1998, ISBN 0-19-509539-1. The curious aspect of this book which is an excellent account of the history of western astronomy, is that, there is not the slightest curiosity, expressed in the book as to the contributions of the Indics

[67] History of Astronomy: An Encyclopedia (Garland Encyclopedias in the History of Science, Volume 1) (Library Binding) by John Lankford (Author) "American astrophysicist and science administrator..."

[68] Hoskin, Michael, "The Cambridge Concise History of Astronomy", Ed. By, Cambridge University Press, Cambridge, UK. 1999

come tumbling down when subjected to a closer look. Furthermore, the carefully cultivated image of an Occident solely concerned with the quest for knowledge using the principles of the scientific method would become a casualty of excessive hubris.

Regardless of the potential for success, it is time that the Indic challenges the Eurocentric descriptions of the development of various sciences and technologies with tenacity and steadfastness. The main motivation for doing so is not merely to claim precedence in the discovery of various episteme where appropriate, but also to establish the legitimate place of the Indic civilization within the diverse family of ethnicities and weltanschauungs that comprise the sum total of the human experience. We owe this much to the giants who came before us and bequeathed such a rich legacy. By the time we are done, we are confident that the name of Yājnavalkya[69] will be well known at least amongst Astronomers as the man who determined that there is a 95 year synchronism between the rotations of the earth and its Moon and that he knew this from the strong traditions of observation that were already established by his time. The current approach to the Sciences and the historical developments that contribute to Civilizational progress is that these are heavily weighted towards Europe. Clearly such an attitude on the part of the Europeans is increasingly resulting in lack of credibility in the traditional accounts of such subjects as the history of astronomy. And then when other civilizations make a legitimate claim on the priority of a particular development, the knee jerk response is that they are claiming to have invented everything. Such emotional responses, that stem from the realization that such a charge (claiming to have invented everything) is more appropriately leveled against the Occidental, are repeated ad nauseum and do not permit a healthy debate to occur and certainly it is not amusing for those of us who are engaged in the serious endeavor of deciphering the past.

W BRENNAND HINDU ASTRONOMY" P.320, CHAPTER 15, 1988

Upon the antiquity of that (Hindu Astronomy) system it may be remarked, that no one can carefully study the information collected by various investigators and translators of Hindu works relating to Astronomy, without coming to the conclusion that long before the period when Grecian learning founded the basis of knowledge and civilization in the West[70], India had its own store of erudition. Masterminds, in those primitive ages, thought out the problems presented by the ever-recurring phenomena of the heavens, and gave birth to the ideas, which were afterwards formed into a settled system for the use and benefit of succeeding Astronomers, mathematicians and Scholiasts, as well as for the guidance of votaries of religion. No system, no theory, no formula concerning those phenomena could possibly have sprung suddenly into existence, at the call or upon the dictation of a single genius. Far rather , is it to be supposed that little by little, and after many arduous labors of numerous minds, and many consequent periods passed in the investigation of isolated phenomena, a system could be expected to be formed into a general science concerning them.

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[69] *Yājnavalkya in the Śatapatha Brāhmaṇa.*

[70] *We assume he is referring to 600 BCE, when the Golden Age of Greece began with Thales of Miletus, Aristarchos, and Hipparchus.*

CHAPTER I
CELESTIAL SPHERE, KHAGOLA-ŚASTRA

INTRODUCTION TO METRICAL OR CALENDRICAL ASTRONOMY - THE APPROACH WE TAKE

The Ancient Vedics seemed to have an obsession for precision as well as a fascination for large numbers. They also subscribed to the notion that the planet earth and the Solar system were of immense antiquity without a beginning, in contrast to the creationist theories propounded by many in the Occident till recently. A combination such as this makes an excellent prerequisite for time keeping and for devising a useful and practical calendar. They turned to the sky and began to decipher the meaning behind the various cycles and periodicities that they observed, in order to help them plan their activities, such as the planting of their crops. The science of discovering these quantities was called Jyotiṣa or Jyotiṣ or Nakṣatra Vidya. The ancient Vedāṅga Jyotiṣa texts declare Jyotiṣa to be Kalá Vidhāna Śāstra, the science of determining time. Bhāskarācarya (Bhāskara II) says that Jyotiṣa is Kalās bodha, knowledge of time. This is amplified by Narsimha Daivajna thus; *the term Kāla also encompasses dik (direction). Now the determination of Kāla, dik, Desa is to be achieved through grahagati pariksha, a study of the motion of celestial objects.*[71]

In order to understand their observations we need a language, a vocabulary, and the modern conceptual framework associated with the visualization of the cosmos known as the Celestial sphere. In this chapter we will lay the groundwork for such a conceptual framework. We will then revert back to the Historical setting in Chapter III, to see how these modern concepts relate to the models and paradigms developed by the ancients. In so doing we have eschewed a chronological approach to the subject in the interest of achieving greater clarity and time; Less of the concepts. We will find that much of this modern framework was present at a very early date in India In the process we have been careful not to sacrifice chronological integrity and have not made the assumption that a particular concept was known before its time, a trap that the Occidental either willingly or unwittingly, falls into when he assumes for example the accreted text of the Almagest is of 2nd century CE vintage.

It is useful for pedagogical purposes to recast ancient knowledge, for example, the paper by Richard Fitzpatrick when he presents the Almagest in a modern form (A Modern Almagest)[72] and that is what we have done in this book, without sacrificing the chronological sequence in which the developments took place. In particular we ascribe to the ancients, any definition that is available in the ancient text similar to the one in the modern one.

THE NOTION OF A FIXED STAR – THE PROPER MOTION

The Celestial objects in the sky exhibit two types of motion. The first motion is such that the whole celestial sphere, and all of the celestial objects attached to it, rotates uniformly from east to west once every 24 (sidereal) hours, in a clockwise (or right handed) direction about a fixed axis passing through the earth's north and south poles. This type of motion is called ***diurnal motion***, and is a consequence of the earth's daily rotation from west to east. Diurnal motion does not disturb the relative angular

[71] I am indebted to Dr. MD Srinivas, the erudite scholar in the topic of Ancient Indian astronomy and mathematics, who has been of great help in identifying and elucidating many areas of research. He had been kind enough to share them generously, these, and many other nuggets of information in a collection of papers, which are listed in the appendix.

[72] Richard Fitzpatrick "A Modern Almagest", http://farside.ph.utexas.edu/syntaxis.html

positions of all celestial objects. However, certain celestial objects, such as the Sun, the Moon, and the planets, undergo a second motion, superimposed on the first, which causes their angular positions to slowly change relative to one another, and to the fixed stars. This *intrinsic motion* of objects in the Solar system is due to a combination of the earth's orbital motion about the Sun, and the orbital motions of the Moon and the planets about the earth and the Sun, respectively. This intrinsic motion of the planets relative to the stars is the reason why they were called planets (or wanderers in Greek). Thus the vast majority of the objects in the sky do not appear to change their position in the sky, since the diurnal motion is imperceptible and hence we use the terminology of **FIXED STARS** when referring to these objects, as opposed to the objects in the Solar system, which while closely resembling the stars in appearance, are entirely of a different character.

In reality it is of course far from true that the fixed stars are fixed in space. They are in fact moving with immense velocities. But, it is difficult to distinguish this motion because of the equally immense distances involved from the observation platform that is the planet earth. The fixed stars exhibit real motion as well, however. This motion may be viewed as having components that consist in part, of motion of the galaxy to which the star belongs, in part, of rotation of that galaxy, and in part, of motion peculiar to the star itself within its galaxy.

This real motion of a star is divided into ***radial*** **motion** and ***proper motion***[73], with "proper motion" being the component across the line of sight. In 1718 Edmund Halley announced his discovery that the fixed stars actually have proper motion. Proper motion was not noticed by ancient cultures because it requires precise measurements over long periods of time to notice. In fact, the night sky today looks very much as it did thousands of years ago, so much so that some modern constellations were first named by the Babylonians.

THE MOTION OF STARS

*M*ost stars have nearly fixed positions in the sky, relative to each other. In fact, they are often referred to as the "fixed stars", in contrast with the planets, which are always in motion relative to each other, and the stellar background.

In reality, however, all stars are in motion relative to each other, and our Galaxy, with velocities of a hundred fifty miles per second or so relative to the center of the Galaxy, and a few tens of miles per second relative to each other. The difference between their rapid motion, relative to the Galaxy, and their much slower motion, relative to each other, is due to the fact that they are mostly going around the Galaxy in nearly the same direction, at nearly the same speed, much as cars on a freeway are heading in nearly the same direction, at nearly the same speed. Under such circumstances, their speeds relative to each other are much smaller than their speeds relative to objects not moving with them.

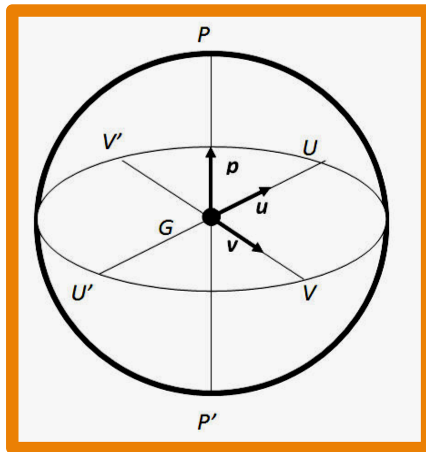
To repeat, the motions of the stars are divided into specific parts, each with its own name and measurement techniques, according to their direction. Motions toward or away from the Sun are measured by Doppler effects -- changes in the apparent wavelength of the light they emit, caused by their radial motion. The motion measured in this way is exemplified by the *radial velocity*, and is considered positive if the radius vector from the Sun to the star is increasing (the star is moving away from us), and negative if the radius vector is decreasing (the star is moving toward us). *Radial velocity can be measured for any star, no matter how distant it is; so long as it is bright enough to spread its light out into a spectrum, and measure the Doppler effect of its motion.* That part of a star's motion that is not toward or away from us is called its tangential motion, and is perpendicular to the radial motion. The

[73] *http://cseligman.com/text/stars/propermotion.htm*

tangential motion is measured by the change in the star's direction in space, over a period of time. If the star is far away, or its tangential motion is small, it may take millennia to observe any change in its position; but if the star is very close to us, so that any motion it has looks relatively large, or if it is at a more moderate distance, but is moving sideways at a rapid rate, we may be able to observe a change in its position and calculate its tangential motion in just a few decades.
The change in a star's position, measured in seconds of arc per year or per century, is referred to as *proper motion*. As explained above, proper motion cannot be measured for all stars -- only for stars which are unusually close, or moving unusually fast relative to the Sun, or both -- and even then, it takes decades or centuries to measure it, whereas radial velocity may be measured as quickly as a spectrum of the star can be obtained, and analyzed. As a result, most stars (and galaxies) have known radial velocities, whereas for most stars (and virtually all galaxies), the proper motion is unknown. There are a only a few stars for which we know the Proper motion, amongst which is Bernard's star which with a proper motion of 10.3 seconds of arc per year, is the second closest stellar system to the Sun, and because it is rapidly approaching the Sun, will be the closest star to the Sun, with a distance of less than four light years, in less than ten thousand years.

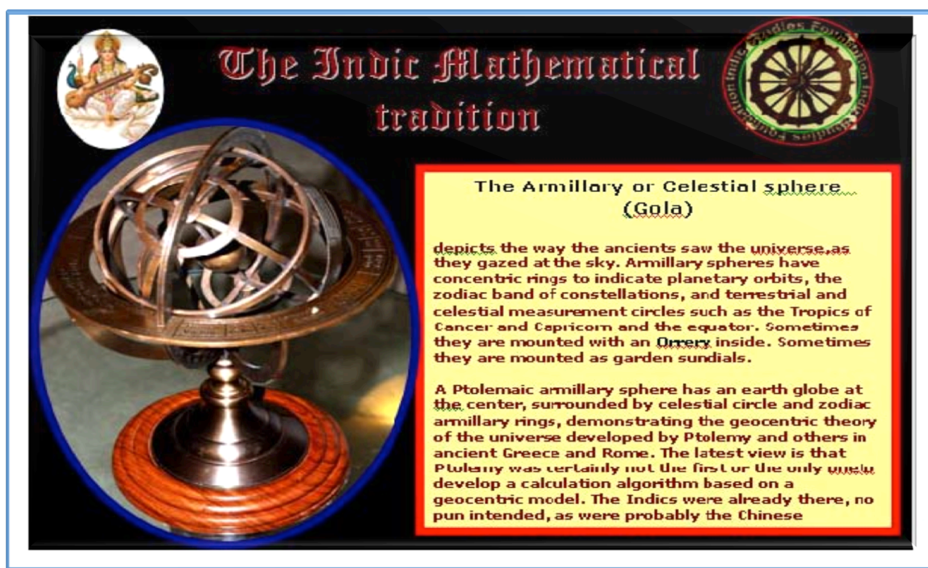
Since stars that are close to the Sun can have relatively small velocities and still have noticeable proper motions, one of the easiest ways to recognize nearby stars is to look for stars with large proper motions. The Sun appears to move about 1^o a day while the Moon moves at a much faster rate (~ 13^O) of approximately an amount equal to its own diameter every hour and completes one revolution in a Lunar month. The motion of the Moon is an actual motion while the motion of the Sun is an apparent motion relative to the Earth. The three periodicities that the ancients used and could be easily observed by the naked eye were the rotation of the earth around the Sun, the rotation of the Moon around the earth and the diurnal revolution of the earth around its own axis. Of course, with rare exceptions they subscribed to a model of the Solar system that was Geocentric, and they assumed that what they actually observed was the rotation of the Sun around the earth and did not realize that the earth was rotating about its own axis.

FIGURE 2 THE CELESTIAL SPHERE, खगोल



In general it has to be admitted that the Indic approach to the measurement and calibration of time and the calendar, has been extraordinarily thorough, and if precision were the sole criterion it is obvious they had an inordinate respect for the importance of such precision. Let us see how they went about developing a calendar that would convey a lot of information merely by knowing the day of the month, after constant observation of the sky both during the day and the night over centuries. The result was a highly efficient and accurate calendar. The added bonus of such a system is the usefulness of the recordings of ancient astronomy to decipher the age at which various events took place, and the development of methods now known collectively as Archeo-astronomy.

FIGURE 1 THE ARMILLARY SPHERE WAS THE FIRST UTILIZED BY ARYABHATA



In this chapter we will give a rather brief historical perspective to Indic astronomy, and in subsequent chapters we will come back to the historical development of the key ideas behind calendrical astronomy when we discuss their approaches to the calendar by other civilizations.

When discussing various calendars, the concern of the Occidental is invariably focused almost exclusively on priority of Invention. He is primarily concerned that the Greeks should not be supplanted as the main source of intellectual ideas in antiquity. We will take a slightly different approach to the issue of priority. We will first discuss the historical perspective of the Indian Calendrical astronomy within the framework of Indian History before we attempt to correlate the dates with the developments in the rest of the world.

The basic information the ancients used for purposes of time keeping were the motions of the sun and the moon relative to the earth. So far nothing unusual, as did all the other ancients. The cycles they used including the day, the week, the fortnight, and the month are shown in table 1. We will expound on the history of Indic astronomy in chapters III, IV, V, and VI, to put the astronomical discoveries in the proper context within the larger canvas of Indic and world history. Contrary to the conventional wisdom of occidental versions of the indic narrative, as exemplified by the writings of David Pingree and his students, india had a very strong and consistent tradition of scholarship in the so called exact sciences of antiquity (as Neugebauer called them) such as astronomy and mathematics. The list of famous astronomers and mathematicians is staggering both in the quantity, and in the quality of the contributions, as well as the time span over which it occurred. We list in Table 1 in chapter XI on Indic savants, significant contributors, to the episteme. That such a list would include a large number of individuals, exceeding 150 in number who made significant contributions, was certainly a revelation for those of us who had little knowledge of the Indic contribution.

It is conceptually useful to visualize the sky as the interior of a vast celestial sphere, but before we do so, let us recapitulate the essential features of the Terrestrial sphere.

THE TERRESTRIAL BHŪGOLA(भूगोल, भूमिगोल), AND CELESTIAL BHĀGOLA (भागोल) SPHERES, THE MODEL OF THE 2 SPHERES

The earth is generally represented as a perfect sphere. Although in reality it is an oblate spheroid (ellipsoid), with a larger diameter at the equator equal to 7,926.41 miles (12,756.32 kilometers). The diameter of the great circle passing through the North and the South Pole is slightly less and is equal to 7,901 miles (12,715.43 km), the difference amounting to .32 %. To specify the location of a particular point on the surface of the earth, we use the measures of longitude and the latitude. The latitude is the angle subtended by the arc of a great circle from the equator to the point. The longitude is the angle subtended by the arc of the equator from the projection of the point to the projection of Greenwich, UK on the great circle. Both these quantities are measured in degrees. The great circle passing through Greenwich is known as the **Prime Meridian (Rekhā),** the ancient Indic used a Prime Meridian passing through Ujjain**.** The great circle making a right angle with the Prime meridian is the Terrestrial Equator **Nirakṣa or Akṣa.** The terrestrial equator slices the earth into 2 hemispheres, the northern, and the southern**.**

Every day **the celestial sphere**, (the interior of a vast sphere centered in the earth) appears to turn in the opposite direction as the earth rotates, causing the daily rising and setting of the Sun, stars, and other

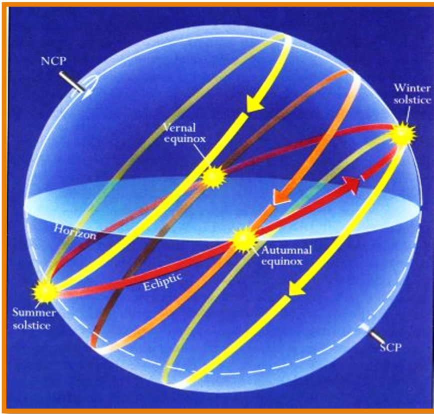


FIGURE 3 CELESTIAL SPHERE INDICATING SOLSTICES AND EQUINOXES

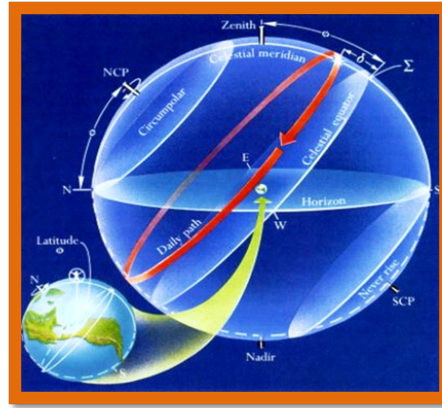


FIGURE 4 HORIZONTAL OR HORIZON COORDINATES

celestial objects (Figure 1). We know now that the sky and the objects in the sky do not rotate (at least not with respect to the earth), but it is an extremely useful construct that serves our purpose of describing the sky and thereby locating the planets and the stars. The Celestial sphere is therefore a vast imaginary sphere with the earth as its center that appears to rotate from East to West. The radius of the celestial sphere was indeterminate.

THE ECLIPTIC (KRĀNTIVṚTTA क्रांतिवृत्त, APAKRAMA अपक्रम) is defined to be the great circle on the celestial sphere that lies in the plane of the earth's Orbit (called the plane of the ecliptic). Because of the earth's annual revolution around the Sun, the Sun appears to move in an annual journey through the heavens with the ecliptic as its path. The ecliptic is inclined to the plane passing through the equator of the earth. It is this inclination that gives rise to the seasons of the year. Six months of the year, from the autumnal equinox to the vernal equinox the southern hemisphere is tilted towards the Sun and the rest of the year , it is the northern hemisphere , that gets the warmer weather.

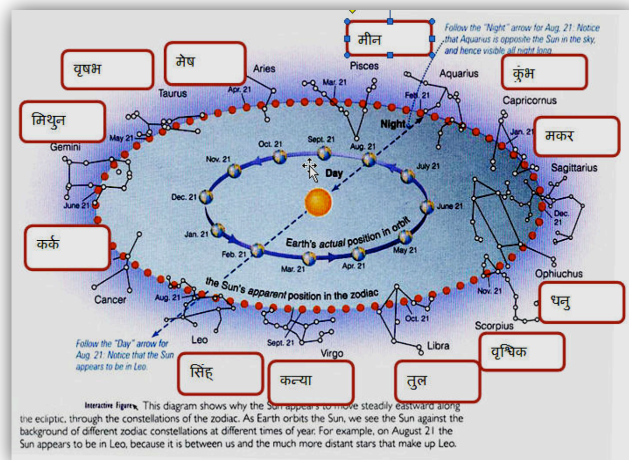


FIGURE 5 SHOWS THE RELATIONSHIP BETWEEN THE RĀŚI AND THE CONSTELLATIONS

The ecliptic is the principal axis in the equatorial coordinate system. The two points at which the ecliptic crosses the **Celestial Equator** are termed the **Equinoxes**. The obliquity of the ecliptic is the inclination of the plane of the ecliptic to the plane of the celestial equator, an angle of about 23 1/2 °. The constellations through which the ecliptic passes are the constellations of the Zodiac (Rāśi). Although the moon's orbit is inclined 5.5 degrees to the Earth's orbital plane, periodically there will come times when it crosses over the ecliptic. **The ecliptic derives its name from the fact that the Moon needs to be on the ecliptic in order for an eclipse to occur.**

The North and South Celestial Poles are determined by extending the line through the North and South Pole (the axis of rotation of the earth), until they intersect the Celestial sphere. (P, P' are the celestial poles in Figure 7)
The **Ecliptic Pole** is the point on the celestial sphere where the sphere meets the imaginary line perpendicular to the ecliptic plane, the path the Earth travels on its orbit around the Sun.

The Armillary sphere was also the model used by the Indics, even though Āryabhaṭa was aware that the earth was spinning on its axis and that it was in reality, a heliocentric system where the earth was merely a planet. Even today, we use a coordinate system that is geocentric while observing the planets and the rest of the Solar system, simply because that is the easiest way to study the sky.

CELESTIAL EQUATOR नाडिवृत्ता,विशुवतवृत्ता , घाटिकवृत्ता
THE COORDINATES OF THE CELESTIAL SPHERE OR EQUATORIAL COORDINATES
Right Ascension (RA), Declination (DEC), Hour Angle (HA).

See Figure 2 THE CELESTIAL SPHERE, the Bhagola. G, P, P’, V, V’ represent the Earth , North Celestial Pole, The South Celestial Pole, Vernal Equinox and Autumnal Equinox, VUV’U’ Is The Celestial Equator And PP’ The Polar Axis.

The circle on the celestial sphere halfway between the celestial poles is called **the celestial equator**; it is called **Višuvad Vṛtta, Nadi Vṛtta or Ghatika Vṛtta**. It can be thought of as the earth's equator projected onto the celestial sphere. It divides the celestial sphere into the northern and southern skies. An important reference point on the celestial equator is the **Vernal Equinox**, the point at which the Sun crosses the celestial equator in March. At this point the Sun has completed half the distance on its annual northward journey or Uttarāyaṇa during its apparent transit though the ecliptic (adapted from Stars, Galaxies and Cosmology, Pearson Education).

Let us establish the coordinate systems.

On any spherical surface, the location of a point in space can be defined by two spherical coordinates. These are 2 angular distances measured on a sphere along arcs of 2 great circles which intersect at right angles. One of the great circles defines a primary and the other at right angles to it is designated a secondary. Depending on how we choose the primary and secondary great circles we can define 3 coordinate systems. The axis of the earth, about which it is spinning, is tilted to the plane of rotation (ecliptic) by about 23 1/2 degrees).

Our location on Earth is expressed through our *latitude* (north-south position; see above) and *longitude*, which gives your east-west position. Similarly we locate a star in the celestial sphere by the terms **Right Ascension (RA, Prakjyakashta)**, which is analogous to longitude and **Declination (DEC**, **Apakrama**), which is analogous to latitude.

It is more convenient to work in equatorial coordinates. Unlike altitude/azimuth coordinates, which are constantly changing as an object rises in the sky, moves across the sky and sets in the west, RA/DEC coordinates don't change as the earth rotates - they form a "fixed" coordinate grid on which stars, galaxies, and so on, are at fixed positions (to a good approximation).All printed star atlases use RA/DEC coordinates. The primary great circle is the Celestial Equator and the secondary great circle is obtained by drawing a circle called a *meridian* from the North Pole through the location to the South Pole. Then do the same through Greenwich, England to define the ***Prime Meridian***[74], and note where they cross the equator. However, RA differs from longitude in essential ways. RA is measured always from the first point of Aries or Meṣa as opposed to the longitude which is measured from the prime meridian through Greenwich, England, and the units are always measured in hours, arc minutes and arc seconds rather than degrees, minutes and seconds. **The star's hour circle** is analogous to a meridian of longitude on earth. In astronomy, **the hour angle** of an object relative to a particular location on earth is one of the coordinates used in the equatorial coordinate system for describing the position of an object on the celestial sphere. The hour angle of a point is the angle between the half plane determined by the earth axis and the zenith (half of the meridian plane) and the half plane determined by the earth axis and the given location, westward of the meridian plane.

The angle is taken with a minus sign if the location is eastward of the meridian plane and with the plus sign if it is located west of the meridian. The hour angle is usually expressed in time units, with 24 hours

[74] *Note that the concept of a Prime Meridian was known to the Ancient Indics, as they used a median passing through Ujjain and Lanka (current day Sri Lanka). It is entirely possible and more than probable that the idea of the meridian came originally from India*

corresponding to a 360^0 diurnal rotation. The HA is usually paired with the declination in order to fully specify the position of an object on the celestial sphere as seen by the observer at a given time. To repeat, the RA of a star or any other celestial body (given by the lower-case Greek letter α is the angle the body makes with the vernal equinox as measured to the east, again along the celestial equator. It too is usually measured in time units. The right ascension and hour angle of body always add to equal the sidereal time. Given the sidereal time and the right ascension of a body, you can compute its hour angle, which with the declination allows you to set a telescope and to find any star.

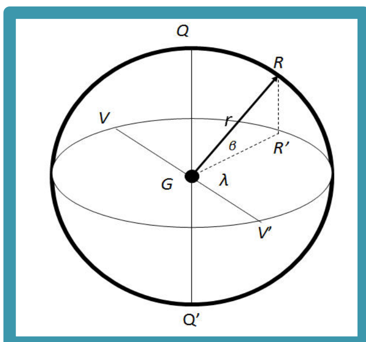


FIGURE 6 THE ECLIPTIC COORDINATES

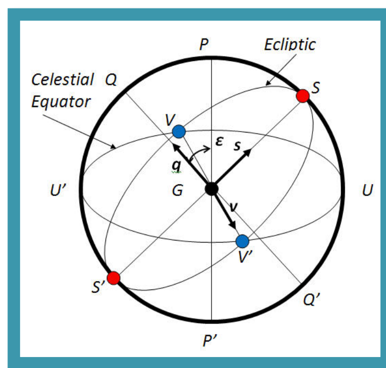


FIGURE 7 ECLIPTIC CIRCLE

The observer measures along the star's hour circle the angle between the celestial equator and the position of the star. This angle is called **the declination of the star and is measured in degrees, arc-minutes, and arc-seconds**[75] north or south of the celestial equator, analogous to latitude on the earth. Right ascension and declination together determine the location of a star on the celestial sphere. The right ascensions and declinations of many stars are listed in various reference tables published for astronomers and navigators. Because a star's position may change slightly (see proper motion and precession of the equinoxes), such tables must be revised at regular intervals. By definition, the vernal equinox is located at right ascension 0 h and declination 0°.

The difference between the Hour angle (HA) and the RA of an object is equal to the current **local sidereal time** (**LST)**, or equivalently,

$HA_{object} = LST - RA_{object}$

SIDEREAL TIME

Thus, the object's hour angle indicates how much sidereal time has passed since the object was on the local meridian. It is also the angular distance between the object and the meridian, measured in hours (1 hour = 15^o). For example, if an object has an hour angle of 2.5 hours, it transited across the local meridian 2.5 sidereal hours ago (i.e., hours measured using sidereal time), and is currently 37.5^o west of the

[75] *The distinction between angular measures and time, both of which have units of minutes and seconds is usually obvious from the context. It is usual to refer to the angular measures as arc minutes and arc seconds, in the event there is possible ambiguity. The equivalence between the two measures in the case of Navigation and Astronomy is explicated in page 452 (endnote)*

meridian.

FIGURE 8 HORIZON COORDINATE SYSTEMS

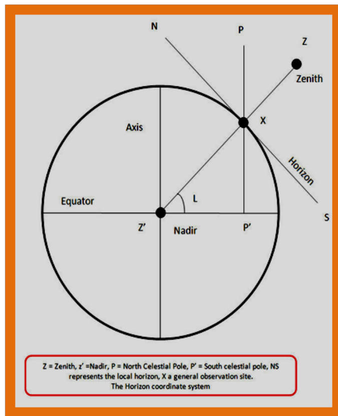
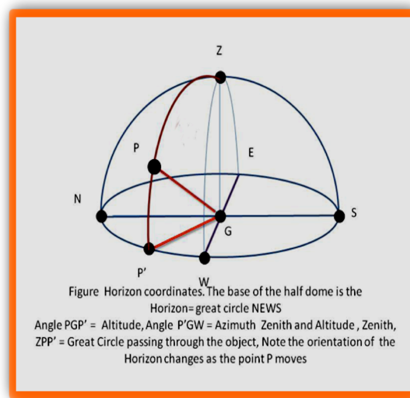


FIGURE 9 HORIZON COORDNATES



Negative hour angles indicate the time until the next transit across the local meridian. Of course, an hour angle of zero means, the object is currently on the local meridian. The usefulness of the hour angle is that it can be measured. **Star time**, properly called **sidereal time**, is the hour angle of the Vernal or Spring Equinox. Because the Sun moves to the east along the ecliptic, the Sun takes longer to make a circuit of the sky on its daily path than does a star or the equinox, so the Solar day is 4 minutes longer than the sidereal day. As a result, the sidereal clock gains 4 minutes (actually 3 minutes 56 seconds) per day over the solar clock, starting from the time of solar passage across the autumnal equinox on September 23, when the two are the same.

Another useful reference point is **the sigma point**, R' the point where the observer's celestial meridian intersects the celestial equator.. The right ascension of the sigma point is equal to the observer's local sidereal time. **The angular distance from the sigma point to a star's hour circle is its hour angle**; it is equal to the star's right ascension minus the local sidereal time. Because the vernal equinox is not always visible in the night sky (especially in the spring), whereas the sigma point is always visible, the hour angle is used in actually locating a body in the sky.

FIGURE 10 ZENITH & ALTITUDE

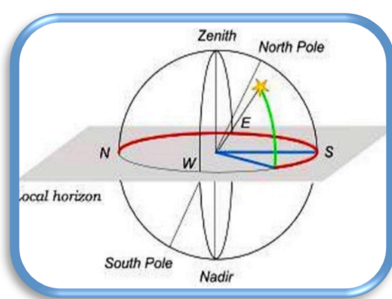
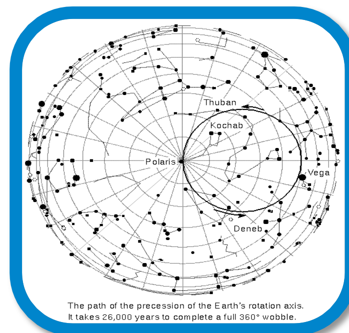
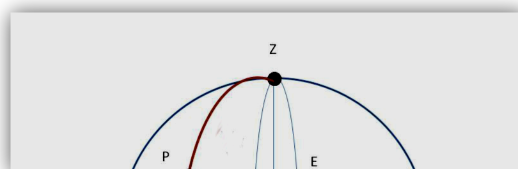


FIGURE 11 ROTATION OF AXIS & POLE STAR DUE TO PRECESSION





ECLIPTIC COORDINATES

The ecliptic coordinate system is a celestial coordinate system that uses the ecliptic for its fundamental plane. The ecliptic is the path that the sun appears to follow across the sky over the course of a year. By definition the sun always lies on the ecliptic. The declination of the Sun is always zero. The ecliptic is known as Apakrama Maṇḍala it is also the projection of the Earth's orbital plane onto the celestial sphere. The latitudinal angle is called the ecliptic or celestial latitude (denoted β), measured positive towards the north. The longitudinal angle is called the ecliptic, tropical or celestial longitude (denoted λ), measured eastwards from 0° to 360°. Like right ascension in the equatorial coordinate system, the origin for ecliptic longitude is the vernal equinox. This choice makes the coordinates of the fixed stars subject to shifts due to the precession, so that always a reference epoch should be specified. Usually epoch J2000.0 is taken, but the instantaneous equinox of the day (called the epoch of date) is possible too. In the Indian system, the epoch has been chosen to be 285 CE. It is possible this was the date of Varāhamihīra, the author of the Pancha Siddhānta. It is also the accepted date for a redaction of the Sūrya Siddhānta.

FIGURE 12 PRECESSION RESULTS IN THE ROTATION OF THE CELESTIAL AXIS ABOUT THE ECLIPTIC AXIS

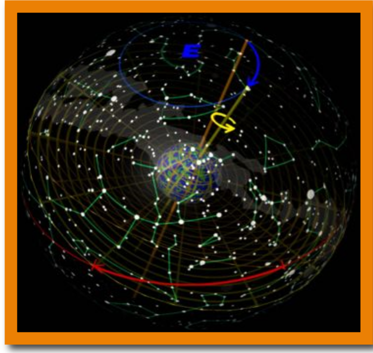
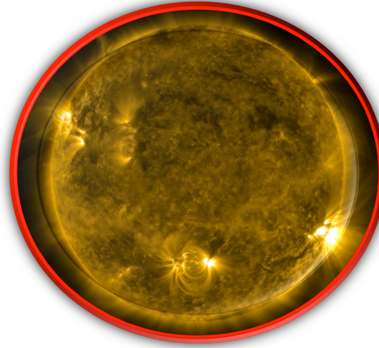


FIGURE 13 PHOTOGRAPH OF THE SUN DURING AUTUMNAL EQUINOX, 2011



$\lambda_t = \lambda_n$ +50.26 (Epoch – 285), λ_t = Sāyaṇa or tropical longitudes, λ_n = Nirāyana or Sidereal longitudes
∡ RGR′ δ = declination, α = Right ascension
VR′V′ Equatorial plane, location of R on celestial sphere is specified by α, δ
GV unit vector in the direction of the equinoxes V, GR′ unit vector orthogonal to v , u
GP unit vector orthogonal to equatorial plane, p, GR = unit vector in the direction of arbitrary location R, r. Sin δ = r.p (note this is a dot product of 2 vectors) , Tan α = r.u/r.v, using vector dot products, s = cos ε u + sin ε p, q = −sin ε u + cos ε p. Where s is a unit vector which is directed from the earth to the summer solstice, and q a unit vector which is directed from the earth to the north ecliptic pole—see Figure 5. We can also write
u = cos ε s − sin ε q, p = sin ε s + cos ε q.
In matrix notation

U = T E, E = T′ U where U = the unit vectors of the equatorial plane.

TABLE 1 THE DAY AND TIME (UTC) OF THE 4 CARDINAL POINTS
THE 4 CARDINAL POINTS – EQUINOXES AND SOLSTICES PRECESSION OF THE EQUINOXES (AYANACALANA) अयनचलन

Year	Vernal Equinox		June Solstice		Autumnal Equinox		December Solstice	
2000	Mar 20	7:35 AM	Jun 21	1:48 AM	Sep 22	5:28 PM	Dec 21	1:38 PM
2001	Mar 20	1:31 PM	Jun 21	7:38 AM	Sep 22	11:05 PM	Dec 21	7:21 PM
2002	Mar 20	7:16 PM	Jun 21	1:25 PM	Sep 23	4:55 AM	Dec 22	1:14 AM
2003	Mar 21	1:00 AM	Jun 21	7:11 PM	Sep 23	10:47 AM	Dec 22	7:04 AM
2004	Mar 20	6:48 AM	Jun 21	12:57 AM	Sep 22	4:30 PM	Dec 21	12:42 PM
2005	Mar 20	12:33 PM	Jun 21	6:46 AM	Sep 22	10:23 PM	Dec 21	6:35 PM
2006	Mar 20	6:25 PM	Jun 21	12:26 PM	Sep 23	4:04 AM	Dec 22	12:22 AM
2007	Mar 21	12:07 AM	Jun 21	6:06 PM	Sep 23	9:51 AM	Dec 22	6:08 AM
2008	Mar 20	5:48 AM	Jun 20	11:59 PM	Sep 22	3:44 PM	Dec 21	12:04 PM
2009	Mar 20	11:44 AM	Jun 21	5:46 AM	Sep 22	9:19 PM	Dec 21	5:47 PM
2010	Mar 20	5:32 PM	Jun 21	11:29 AM	Sep 23	3:09 AM	Dec 21	11:39 PM
2011	Mar 20	11:21 PM	Jun 21	5:16 PM	Sep 23	9:05 AM	Dec 22	5:30 AM
2012	Mar 20	5:14 AM	Jun 20	11:09 PM	Sep 22	2:49 PM	Dec 21	11:12 AM
2013	Mar 20	11:02 AM	Jun 21	5:04 AM	Sep 22	8:44 PM	Dec 21	5:11 PM
2014	Mar 20	4:57 PM	Jun 21	10:52 AM	Sep 23	2:29 AM	Dec 21	11:03 PM
2015	Mar 20	10:45 PM	Jun 21	4:38 PM	Sep 23	8:21 AM	Dec 22	4:48 AM
2016	Mar 20	4:30 AM	Jun 20	10:35 PM	Sep 22	2:21 PM	Dec 21	10:44 AM
2017	Mar 20	10:29 AM	Jun 21	4:24 AM	Sep 22	8:02 PM	Dec 21	4:28 PM
2018	Mar 20	4:15 PM	Jun 21	10:07 AM	Sep 23	1:54 AM	Dec 21	10:22 PM
2019	Mar 20	9:59 PM	Jun 21	3:54 PM	Sep 23	7:50 AM	Dec 22	4:19 AM
2020	Mar 20	3:50 AM	Jun 20	9:44 PM	Sep 22	1:31 PM	Dec 21	10:03 AM
2021	Mar 20	9:37 AM	Jun 21	3:32 AM	Sep 22	7:21 PM	Dec 21	3:59 PM
2022	Mar 20	3:33 PM	Jun 21	9:14 AM	Sep 23	1:04 AM	Dec 21	9:48 PM
2023	Mar 20	9:24 PM	Jun 21	2:57 PM	Sep 23	6:50 AM	Dec 22	3:27 AM
2024	Mar 20	3:06 AM	Jun 20	8:51 PM	Sep 22	12:44 PM	Dec 21	9:20 AM
2025	Mar 20	9:02 AM	Jun 21	2:42 AM	Sep 22	6:20 PM	Dec 21	3:03 PM
2026	Mar 20	2:46 PM	Jun 21	8:25 AM	Sep 23	12:05 AM	Dec 21	8:50 PM
2027	Mar 20	8:25 PM	Jun 21	2:11 PM	Sep 23	6:02 AM	Dec 22	2:42 AM
2028	Mar 20	2:17 AM	Jun 20	8:02 PM	Sep 22	11:45 AM	Dec 21	8:20 AM
2029	Mar 20	8:02 AM	Jun 21	1:48 AM	Sep 22	5:38 PM	Dec 21	2:14 PM
2030	Mar 20	1:52 PM	Jun 21	7:31 AM	Sep 22	11:27 PM	Dec 21	8:10 PM
2031	Mar 20	7:41 PM	Jun 21	1:17 PM	Sep 23	5:15 AM	Dec 22	1:56 AM
2032	Mar 20	1:22 AM	Jun 20	7:09 PM	Sep 22	11:11 AM	Dec 21	7:56 AM
2033	Mar 20	7:23 AM	Jun 21	1:01 AM	Sep 22	4:52 PM	Dec 21	1:46 PM
2034	Mar 20	1:18 PM	Jun 21	6:44 AM	Sep 22	10:40 PM	Dec 21	7:34 PM
2035	Mar 20	7:03 PM	Jun 21	12:33 PM	Sep 23	4:39 AM	Dec 22	1:31 AM
2036	Mar 20	1:03 AM	Jun 20	6:32 PM	Sep 22	10:24 AM	Dec 21	7:13 AM
2037	Mar 20	6:50 AM	Jun 21	12:22 AM	Sep 22	4:13 PM	Dec 21	1:08 PM
2038	Mar 20	12:40 PM	Jun 21	6:09 AM	Sep 22	10:02 PM	Dec 21	7:02 PM

2039	Mar 20	6:32 PM	Jun 21	11:57 AM	Sep 23	3:50 AM	Dec 22	12:40 AM
2040	Mar 20	12:11 AM	Jun 20	5:47 PM	Sep 22	9:45 AM	Dec 21	6:33 AM
2041	Mar 20	6:07 AM	Jun 20	11:36 PM	Sep 22	3:27 PM	Dec 21	12:18 PM
2042	Mar 20	11:53 AM	Jun 21	5:16 AM	Sep 22	9:12 PM	Dec 21	6:04 PM
2043	Mar 20	5:28 PM	Jun 21	10:58 AM	Sep 23	3:07 AM	Dec 22	12:01 AM
2044	Mar 19	11:20 PM	Jun 20	4:51 PM	Sep 22	8:48 AM	Dec 21	5:44 AM
2045	Mar 20	5:07 AM	Jun 20	10:34 PM	Sep 22	2:33 PM	Dec 21	11:35 AM
2046	Mar 20	10:58 AM	Jun 21	4:15 AM	Sep 22	8:22 PM	Dec 21	5:28 PM
2047	Mar 20	4:53 PM	Jun 21	10:03 AM	Sep 23	2:08 AM	Dec 21	11:07 PM
2048	Mar 19	10:34 PM	Jun 20	3:54 PM	Sep 22	8:01 AM	Dec 21	5:02 AM
2049	Mar 20	4:29 AM	Jun 20	9:47 PM	Sep 22	1:43 PM	Dec 21	10:52 AM

THE THREE PERIODICITIES

Once we have a means of describing the location of an object in the sky, we can study the effects of the 3 periodicities:

1. The diurnal rotation of the earth around its own axis, which was accounted for as a diurnal rotation of the entire KHAGOLA (CELESTIAL SPHERE). Aryabhata realized that the two models were equivalent for the instances that he was studying this phenomena. But he could not make the final step.
(See page 49-50)

2. The motion of the moon around the earth,
3. and the annual rotation of the earth around the Sun.

The celestial equator and the ecliptic are the two main great circles around which the positions of their heavenly bodies are situated in the ancient text of the Sūrya Siddhānta. The units used in the Sūrya Siddhānta are the same as those in use today.

One bhagana (revolution) = 12 Rāśi, One Rāśi= 30 amsas (degrees), One day= 30 muhurtas, One amsa= 60 kalas (minutes), One kala = 60 vikalas (seconds).

The word "equinox" derives from the Latin words meaning "equal night" and refers to the time when the Sun crosses the equator. At such times, day and night are everywhere of nearly equal length (12 hours each) everywhere in the world. Thus an equinox is either of two points on the celestial sphere where the ecliptic and the celestial equator intersect. The vernal equinox, also known as "the first point of Aries," is the point at which the Sun appears to cross the celestial equator from south to north. This occurs about Mar. 21, marking the beginning of spring in the Northern Hemisphere. This is the zero point of the Right Ascension coordinate or the halfway point during the northward journey of the Sun. This can be conceptualized more familiarly as the Celestial Longitude. At the autumnal equinox, about Sept. 23, the Sun again appears to cross the celestial equator, this time from north to south; this marks the beginning of autumn in the Northern Hemisphere. The equinoxes are not fixed points on the celestial sphere but move westward along the ecliptic, passing through all the constellations of the Zodiac in approximately 25,800 years. This motion is called the precession of the equinoxes. The vernal equinox is a reference point in the equatorial coordinate system.

The earth revolves around the Sun once in **365^d 5^h 48^m 46.08^s .** Thus, in what is now termed a geocentric model, the Sun appears to complete one round of the ecliptic during this period. This is called a tropical year. It is important to realize that the earth does not complete a full 360^o revolution during a tropical year but falls shy by 50.26^s. In the span of a tropical year; the earth regains its original angular position with the Sun. It is also called the year of seasons, since the seasons depend on this Earth-Sun cycle. If we consider the revolution of the Sun around the earth from one vernal equinox (around 21st March, when the day and night all over they are equal) to the next vernal equinox, it takes one tropical year to do so. Globe: However, if at the end of a tropical year from one vernal equinox to the next, we consider the position of the earth with reference to a fixed star of the Zodiac, the earth appears to lie some 50.26 seconds of celestial longitude to the west of its original position. In order for the earth to attain the same position with respect to a fixed star after one revolution, it takes a time span of **365^d 6^h 9^m 9.8^s** seconds. This duration of time is called a sidereal year .The sidereal year is just over 20 minutes longer than the tropical year. Each year, the Vernal equinox will fall short by 50.26 seconds along the Zodiac reckoned along the fixed stars. This continuous receding of the Vernal equinox along the Zodiac is called the Precession of the equinoxes. Thus the Precession of the equinoxes and of the solstices is a westward movement of the cardinal points in the celestial sphere. Its main component is caused by the equatorial bulge, and is known as the **Luni-solar precession** and there is a small secondary effect due to the planets called the **planetary precession**. The sum of these two is known as the **General Precession.** Thus the Makar Saṃkrāṇti which used to occur on December 22 now falls on January 15 and the Kārka Saṃkrāṇti now falls on April 15 instead of March 23.

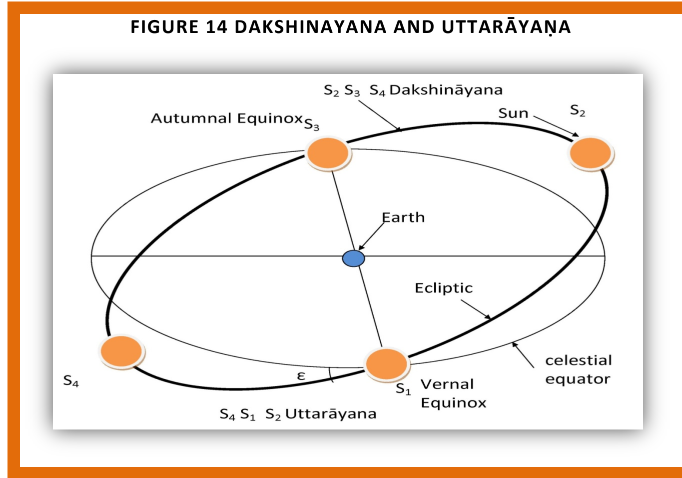
As a consequence of the precession, the celestial pole makes a complete circle approximately every **N_p $\cong$ $25{,}784^y$** , the centre of the circle being the ecliptic pole (see Figure 9, 10). Also as a consequence of the precession, the right ascension and declination of the stars are continuously changing, since we use equatorial coordinates to define these quantities. In order to maintain simplicity in describing phenomena it is therefore customary to use Nirāyana coordinates, using a specific epoch, such as the Lahiri epoch.

SOLSTICE (अयनन्त)

A solstice is an astronomical event that happens twice a year, when the tilt of the Earth's axis is most oriented toward or away from the Sun, causing the Sun to reach its northernmost or southernmost extreme. The name is derived from the Latin *sol* (sun) and *sistere* (to stand still), because at the solstices, the Sun stands still in declination; that is, it’s apparent movement north or south comes to a standstill. The Summer Solstice falls between June 20 and 23 of every year in the northern hemisphere and has different significance for various religions.

The term solstice can also be used in a wider sense, as the date (day) that such a passage happens. The solstices, together with the equinoxes, are connected with the seasons. In some languages they are considered to start or separate the seasons; in others they are considered to be centre points.

FIGURE 14 DAKSHINAYANA AND UTTARĀYAṆA



SUMMER SOLSTICE: The first day of the Season of Summer. On this day (JUNE 21 in the northern hemisphere) the Sun is farthest north and the length of time between sunrise and sunset is the longest of the year.

WINTER SOLSTICE: The first day of the Season of Winter. On this day (e.g. December 22 in the northern hemisphere) the Sun is farthest south and the length of time between sunrise and sunset is the shortest of the year.

SOLSTITIAL DIVISION OF YEAR (UTTARĀYAṆA AND DAKṢIṆĀYANA)

The Indian subcontinent is heavily dependent on the Monsoons, and they arrive very precisely. It was noticed also by the Ancients that there was a periodicity in the incidence of the Solstices. As a result they spent inordinate amount of observations to understand the relationship between the solstices and the equinoxes and, after collecting all this data, they were able to determine that in fact the solstices were not invariant with reference to the fixed stars. The value of the precessional rate they came up with is in fact more accurate than the one found by Hipparchus[76]. The passage from the winter solstice to the summer solstice is called the *Uttarāyaṇa* (उत्तरायण) as the Sun appears to be moving to the northern latitudes and conversely, the passage from June till December is called the *Dakşiṇāyana* दक्षिणायन, when the Sun appears to be heading to the southern hemisphere. Further the part of the ecliptic, in which the Sun appears to be north of the Equator from March 21 to September 23 is called the **Devayana** and the rest of the ecliptic when the Sun is to the South of the Equator from September 23 to March 21 is called the *Pitruyana* (पितृयन)

The Uttarāyaṇa begins at the nominal winter solstice, but this day no longer coincides with the Makara-Saṃkrāṇti which is celebrated on January 15; and the day on which this solstice occurs, is now December

[76] *see for instance chapter III*

73 J. Chapront, M. Chapront-Touzé and G. Francou, A new determination of lunar orbital parameters, precession constant and tidal acceleration from LLR measurements , A&A 387, 700-709 (2002) , DOI: 10.1051/0004-6361:20020420, Observatoire de Paris - SYRTE - UMR 8630/CNRS, 61 avenue de l'Observatoire, 75014 Paris, France (Received 13 December 2001 / Accepted 5 March 2002)

21/22. The corresponding Nakṣatra, is still a special occasion of festivity and rejoicing**.** **Dakṣiṇāyana** begins at the nominal summer year solstice, as marked by the Karka-Saṃkrāṇti. It may be added here that, while the Hindus disregard precession in the actual computation of their years and the regulation of their calendar, they pay attention to it in certain other respects, and notably as regards the solstices: the Precessional solstices are looked upon as auspicious occasions, as well as the non-precessional solstices, and are customarily shown in the almanacs; and some of the almanacs show also the other Precessional Saṃkrāṇti of the Sun. In the southern hemisphere, winter and summer solstices are exchanged. Summer: December 22. Winter: June 21. The Indian calendrical system is based on sidereal measurements. In order to understand the system we need to recall some definitions of the year, month, and the day.

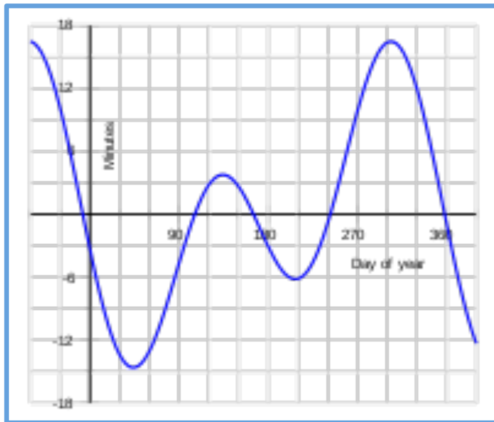


FIGURE 15 EQUATION OF TIME

S1 = Vernal Equinox, S_2 =Summer Solstice, S3 = Autumnal Equinox, S4 = Winter Solstice

MORE DEFINITIONS

Dakṣiṇāyana दक्षिणायन, the path taken by the Sun from Summer Solstice to Winter Solstice, the Southbound journey of the sun.

Uttarāyaṇa उत्तरायण, the path taken by the Sun from Winter Solstice to Summer Solstice, the northbound journey of the sun

Colure – The great circle through the Celestial Poles and through the Equinoxes is called the Equinoctial colure. The great circle through the Poles and the solstices is called the Solstitial colure. Hour Circle is a great circle passing through the north and south celestial poles.

Parallels of declination are small circles parallel to the plane of the equator.

Meridian - The Local Celestial Meridian is the great circle that passes through the North Celestial Pole and a particular location.

Apparent Solar Time Apparent Solar time is given by the hour angle of the Sun plus 12 hours (the 12 hours added so that the "day" starts at midnight). Because of the Eccentricity of the Earth's orbit and the obliquity of the ecliptic, apparent Solar time does not keep a constant pace. Corrections for their effects lead to constant mean Solar time, which can differ from apparent Solar time by up to 17 minutes**.** The hour angle of the Sun, and therefore the time of day, varies continuously with longitude, wherein longitude differences exactly equal time differences. Standard times are the mean Solar times of the closest standard meridians, which are displaced in units of 15° from Greenwich. (Political boundaries cause variances.)

Mean Solar Time is conceived using the notion of a fictitious Sun moving at a constant angular velocity, which will permit it to complete one orbit in the same amount of time.

EQUATION OF TIME (SEE ALSO ANALEMMA IN THE GLO-PEDIA)

Since observations made on the Sun for the purpose of determining the time can give apparent time only, it was necessary, for the purpose of maintaining accurate times in clocks, to be able to find at any

instant, the exact relation between apparent time and Mean time. The equation of time expresses the variability in the orbiting velocity of the planet (in this case the earth) — above the axis the dial will appear *fast*, and below the dial will appear *slow*.

The **equation of time** is the difference between apparent solar time and mean solar time, both taken at a given place (or at another place with the same geographical longitude) at the same real instant of time.

Apparent (or true) solar time can be obtained for example by measurement of the current position (hour angle) of the Sun, or indicated (with limited accuracy) by a sundial. *Mean* solar time, for the same place, would be the time indicated by a steady clock set so that its differences over the year from apparent solar time average to zero (with zero net gain or loss over the year).

The equation of time varies over the course of a year, in a way that is almost exactly reproduced from one year to the next. Apparent time, and the sundial, can be ahead (fast) by as much as $16^m\ 33^s$ (around 3 November), or behind (slow) by as much as $14^m\ 6^s$ (around 12 February).

The equation of time results mainly from two different superposed astronomical causes (explained below), each causing a different non-uniformity in the apparent daily motion of the Sun relative to the stars, and contributing a part of the effect:

The obliquity of the ecliptic (the plane of the Earth's annual orbital motion around the Sun), which is inclined by about 23.44 degrees relative to the plane of the Earth's equator; and

The Eccentricity and elliptical form of the Earth's orbit around the Sun.

The equation of time is also the east or west component of the Analemma, a curve representing the angular offset of the Sun from its mean position on the celestial sphere as viewed from Earth.

The amplitude of the Equation of Time is 9.87 minutes. The formula for computing the **Equation of Time is, E = 9.87 Sin (2 β) – 7.53 Cos (β) – 1.5 Sin (β)** (**E is in minutes**)

Where **β** = **360 degrees (N – 81)/ 364**

The equation of time was used historically to set clocks. Between the invention of accurate clocks in 1656 and the advent of commercial time distribution services around 1900, one of two common land-based ways to set clocks was by observing the passage of the Sun across the local meridian at noon. The moment the Sun passed overhead, the clock was set to noon, offset by the number of minutes given by the equation of time for that date. (The second method did not use the equation of time, it used stellar observations to give sidereal time, in combination with the relation between sidereal time and solar time.) The equation of time values for each day of the year, compiled by astronomical observatories, was widely listed in almanacs and ephemerides.

Naturally, other planets will have an equation of time too. On Mars the difference between sundial time and clock time can be as much as 50 minutes, due to the considerably greater Eccentricity of its orbit (the Eccentricity of the orbits of the planets is given).

Sidereal Time - During the course of one day, the earth has moved a short distance along its orbit around the Sun, and so must rotate a small extra angular distance before the Sun reaches its highest point. The stars, however, are so far away that the earth's movement along its orbit makes a generally negligible difference to their apparent direction (see, however parallax), and so they return to their highest point in slightly less than 24^h. A mean sidereal day is about $23^h\ 56^m$ in length. Due to variations in the rotation rate of the Earth, however, the rate of an ideal sidereal clock deviates from any simple multiple of a civil clock.

THE YEAR (SAMVATSARA)

A Solar *year (Sāyana) and* a ***S**idereal (Nirāyana) year* both refer to the amount of time it takes Earth to revolve about the Sun. The difference between the two measures is in the reference point for each revolution. The Latin root of *sidereal* is *sidereus,* "starry," which itself comes from *sides,* "star, installation." The Latin root of Solar is *solis,* "sun." Thus, the difference between a Solar year and a sidereal year is the difference in time between one complete revolution of Earth relative to the Sun, and one complete revolution of the earth relative to the constellations respectively.

TROPICAL YEAR

A **tropical year** (also known as a Solar year) सायन is the length of time the Sun, as seen from the Earth, takes to return to the same position along the ecliptic (its path among the stars on the celestial sphere)) relative to the equinoxes and solstices, or the time interval needed for the mean tropical longitude of the Sun to increase by 2π (360 sexagesimal degrees, a complete turn). The length of time depends on the starting point on the ecliptic.
The *tropical year* is the time taken by the Sun to complete one circuit of the celestial sphere from one vernal equinox to the next. It is thus the interval between two successive March Equinoxes. Due to shortening effects of precession of the Equinoxes, the Earth makes a revolution of less than 360^o around the Sun to return to the March Equinox. Hence the tropical year, of mean length about **365^d 5^h 48^m 46.08^s** (**365.2422^d**), is shorter than the sidereal year by about 20 minutes.

There is some choice in the length of the tropical year depending on the point of reference that one selects. The reason is that, while the precession of the equinoxes is fairly steady, the apparent speed of the Sun during the year is not. When the Earth is near the **perihelion** of its orbit (presently, around January 3 – January 4), it (and therefore the Sun as seen from Earth) moves faster than average; hence the time gained when reaching the approaching point on the ecliptic is comparatively small, and the "tropical year" as measured for this point will be longer than average. This is the case if one measures the time for the Sun to come back to the southern solstice point (around December 21 – 22 December), which is close to the perihelion.

The northern solstice point is now near the aphelion, where the Sun moves slower than average. The time gained because this point approached the Sun (by the same angular arc distance as happens at the southern solstice point) is greater. The tropical year as measured for this point is shorter than average. The equinoctial points are in between, and at present the tropical years measured for these are closer to the value of the mean tropical year as quoted above. As the equinox completes a full circle with respect to the perihelion (in about 21,000 years), the length of the tropical year as defined with reference to a specific point on the ecliptic oscillates around the mean tropical year. Current mean values and their annual change of the time of return to the cardinal ecliptic points are in Julian years from 2000:

TABLE 2 THE PERIODICITIES OF THE 4 CARDINAL POINTS ON THE ORBIT	
vernal equinox	365.242 374 04 + 0.000 000 103 38×a days
northern solstice	365.241 626 03 + 0.000 000 006 50×a days
autumn equinox	365.242 017 67 − 0.000 000 231 50×a days
southern solstice	365.242 740 49 − 0.000 000 124 46×a days
average	365.242 189 56 − 0.000 000 061 52×a days

The average of these four is **365.2422^d (**SI days or the mean tropical year). This figure is currently getting smaller, which means years get shorter, when measured in seconds. Now, actual days get slowly and steadily longer, as measured in seconds. So the number of actual days in a year is decreasing too. Starting from the (northern) vernal equinox, one of the four cardinal points along the ecliptic, yields the **vernal equinox year**; averaging over all starting points on the ecliptic yields the **mean tropical year**. More specifically, the *tropical year* is defined as the mean interval between vernal equinoxes; it corresponds to the cycle of the seasons. While these measures of time are popularly referred to as astronomical constants they are in reality constantly changing with time The following expression, based on the orbital elements of Laskar (1986), is used for calculating the length of the tropical year:

K_t = 365.2421896698 – 6.15359E-6 T - 7.29E-10 T^2 + 2.64E-10 $T^{3\ k}$ [days]

Where **T = (JD - 2451545.0)/36525** and JD is the Julian day number and T is in Julian centuries from epoch 2000. However, the interval from a particular vernal equinox to the next may vary from this mean by several minutes.

A **Calendar Year** is the time between two dates with the same name in a calendar.

The Anomalistic Year is the time taken for the Earth to complete one revolution with respect to its apsides. The orbit of the Earth is elliptical; the extreme points, called apsides, are the perihelion (when the perigee refers to planetary motion), where the Earth is closest to the Sun (January 3 in 2010), and the aphelion, where the Earth is farthest from the Sun (July 6 in 2010). The anomalistic year is usually defined as the time between two successive perihelion passages. Its average duration is:

Anomalistic Year = **365.259 635 864^d (365^d 6^h 13^m 52^s**) (at the epoch 2000.0).

The anomalistic year is slightly longer than the sidereal year because of the precession of the apsides (or anomalistic precession).

THE ORBIT OF THE EARTH AROUND THE SUN

The orbit of the earth around the Sun is for all practical purposes a circle, since the Eccentricity of the orbit e = 0.0167 is very small, but these small differences in ellipticity are enough to cause significant climatic changes on the earth. The distance from the Sun varies between 91.5 million miles to 94.5 million miles, in Angstrom units (AU); it goes from .983 AU at Perihelion to 1.017 AU at the Aphelion. The error in assuming the orbit to be an exact ellipse is even more miniscule. Each of these quantities provides a unique piece of information about the orbit. For the orbit of the earth, the following are current values.

Elongation is the angular distance between the sun, and another object such as a moon or a planet as seen from earth. There are several special names for these angular distances. The different names of these angles depend on the status, inferior or superior, of the planet.

The planets closer to the sun than the earth are called inferior planets. The planets farther away from the sun than earth are called superior planets. Elongation is measured from earth as the angle between the sun and the planet. Sometimes the apparent relative position of a planet in relation to the sun is called the aspect, or configuration, of a planet.

A list of the abbreviations used in the image follows:

ELEMENTS OF AN ORBIT (SEE FIGURE 18)
An orbit is described by 6 quantities known as elements. They are the
Semi major axis a,
Eccentricity e,
Inclination i,
Longitude of the ascending node Ω (the Vernal Equinox)
Longitude of the perihelion ω
Time of the perihelion passage T

Conjunction occurs when the two solar system objects on the celestial sphere lie on the same great circle from the north celestial pole to the south celestial pole. For planets, this alignment is with the sun and a planet. A superior planet is said to be in conjunction when it is on the other side of the sun as seen from earth. An inferior planet can be in superior or inferior conjunction.

Superior conjunction occurs when the planet is on the other side of the sun as seen from earth. Inferior conjunction occurs when planet is between the sun and the earth. The moon is at conjunction when it is between the earth and the sun. When we say that the Vernal Equinox occurs in a particular Nakṣatra what we mean is that the Sun is in conjunction with the particular Yogatārā at a RA of 0^h.

An **occultation** is an event that occurs when one object is hidden by another object that passes between it and the observer. The word is used in astronomy (see below) and can also be used in a general (non-astronomical) sense to describe when an object in the foreground occults (covers up) objects in the background. For a Lunar eclipse to occur there must be an occultation of the Moon by the Sun. Every time an occultation occurs, an eclipse also occurs. Consider a so-called "eclipse" of the Sun by the Moon, as seen from Earth. In this event, the Moon physically moves between Earth and the Sun, thus blocking out a portion or the entire bright disk of the Sun.

Although this phenomenon is usually referred to as an "eclipse", this term is a misnomer, because the Moon is not *eclipsing* the Sun; instead the Moon is *occulting* the Sun. When the Moon *occults* the Sun, it casts a small shadow on the surface of the Earth, and therefore the Moon's shadow is partially eclipsing

Earth. So a so-called "solar eclipse" actually consists of (i) an *occultation* of the Sun by the Moon, as seen from Earth, and (ii) a partial *eclipse* of Earth by the Moon's shadow. By contrast, an "eclipse" of the Moon, a lunar eclipse is in fact a true eclipse: the Moon moves into the shadow cast back into space by Earth, and is said to be *eclipsed* by Earth's shadow. It is said to be in opposition to the Sun. As seen from the surface of the Moon, Earth passes directly between the Moon and the Sun, thus blocking or *occulting* the Sun as seen by a hypothetical lunar observer. Again, every *eclipse* also entails an *Occultation.*

TABLE 3 ORBITAL CHARACTERISTICS OF EARTH	
Orbital Characteristics	Value
epoch	J2000
Aphelion. ***a(1+e)***	152,097,701 km, ,1.0167103335 AU
Perihelion. ***a(1-e)*****,**	147,098,074 km , 0.9832898912 AU
semi major axis, ***a***	149,597,887.5 km , 1.0000001124 AU
Eccentricity, ***e***	0.016710219
Inclination, ***i***	Reference (0) , 7.25° to Sun's equator
ascending node, Ω	348.73936°
Argument of perigee, Ω	114.20783°
Sidereal period Y_s**,**	365.256366^d, 1.0000175^y
Average speed	29.783 km/s , 107,218.00 km/h

Inferior planets are never very far from the sun as seen from earth. When the planet seems to follow the sun, as seen from earth, appearing east of the sun in the evening, the planet is in Opposition can only occur for the moon or superior planets, because the inferior planets do not cross the orbit of the earth. This occurs when the earth is between the sun and the moon or planet. This is the most favorable time to observe superior planets because the planet is visible all through the night and it crosses the celestial meridian at about midnight (solar time) eastern elongation. When the planet seems to precede the sun, being west of the sun in the morning, it is in western elongation. The two most favorable times to observe an inferior planet are in its eastern or western greatest elongation, the two times when the planet appears farthest away from the sun as seen from earth.

Quadrature is when the angle from the sun to an object is a right angle. This can only occur for superior planets or the moon. A planet can be in either eastern or western quadrature. When a planet is in western quadrature, it is overhead at sunrise. When a planet is in eastern quadrature, it is overhead at sunset. The types of elongation are shown in Figure 16.

ELONGATIONS OF THE PLANETS	
E: Earth	IC: Inferior Conjunction
S: Sun	EGE: Eastern Greatest Elongation
C: Conjunction	WGE: Western Greatest Elongation

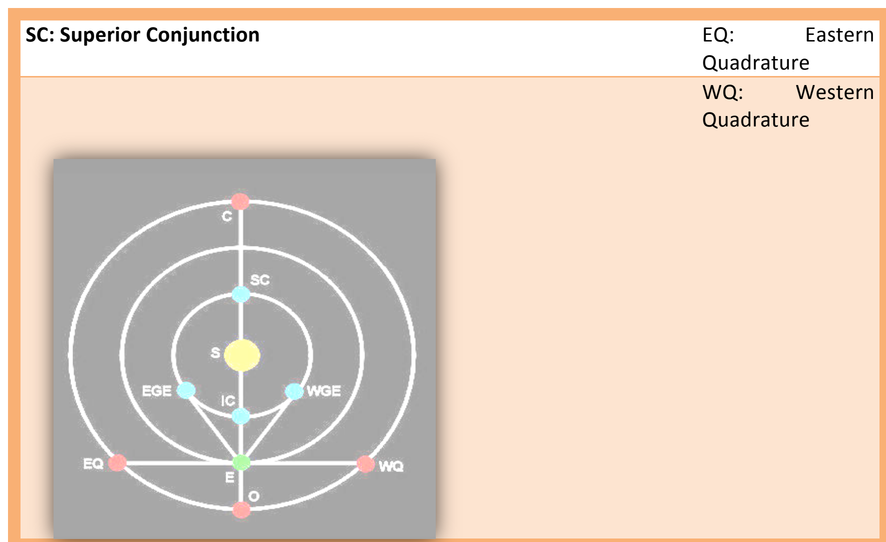
SC: Superior Conjunction	EQ: Eastern Quadrature
	WQ: Western Quadrature

FIGURE 16 THE DIFFERENT ELONGATIONS OF THE PLANETS

THE CONSEQUENCES OF PRECESSION ON THE PERIHELION OF THE SOLAR ORBIT.

The perihelion and aphelion are the two points in the earth's orbit around the Sun where the earth is closest to and farthest from the Sun respectively. (See Glo-pedia). Since the orbit is an ellipse and the Sun is onthe foci of the ellipse, the 4 cardinal points of the orbit namely the 2 Equinoctial points and the 2 solstitial points are not traversed in equal times. This is a consequence of Kepler's second law, the law of areas. As a consequence, the velocity of the earth increases as it gets closer to the perihelion.

The time taken to traverse from AE to VE is 179.06^d whereas the return trip from VE to AE takes 186.18^d. This elementary observation shows that the Eccentricity of the orbit of the earth is not exactly zero. The equator cuts the orbit into two parts having areas in the proportion 186.18 to 179.06, while a diameter cuts the orbit into equal parts. So the Eccentricity of the orbit of the Earth can therefore be estimated approximately, using the following expression,

T_w = Time taken to traverse from AE to VE in days, T_s = Time Taken to traverse from VE to AE in days e $\approx$ $\frac{\pi}{4}(\frac{Ts-Tw}{Ts+Tw}) = \frac{\pi}{4}(\frac{186.18-179.06}{186.18+179.06})$ ≈.0153 (versus the true value of 0.0167)

Note that the exact value of the Eccentricity can be calculated, from the semi-major ***a*** and semi-minor axes ***b*** of the ellipse, using the following formulae;

$e = (r_{ap} - r_{pe}) / (r_{ap} + r_{pe}) = (r_{ap} - r_{pe}) / 2$, $r_{ap} = (1 + e)\, a$, $r_{pe} = (1 - e)\, a$

$$e = \sqrt{(1 - \frac{b}{a})},$$

r_{ap} = the radius at aphelion, r_{pe} =the radius at perihelion.

For the earth orbit, using the values given above for the distances to the perihelion and aphelion***, e =*** (using values from table 3).

*(*1.0167103335 - *.9832898912)/(*1.0167103335 + *.9832898912) =* 0.0167102193

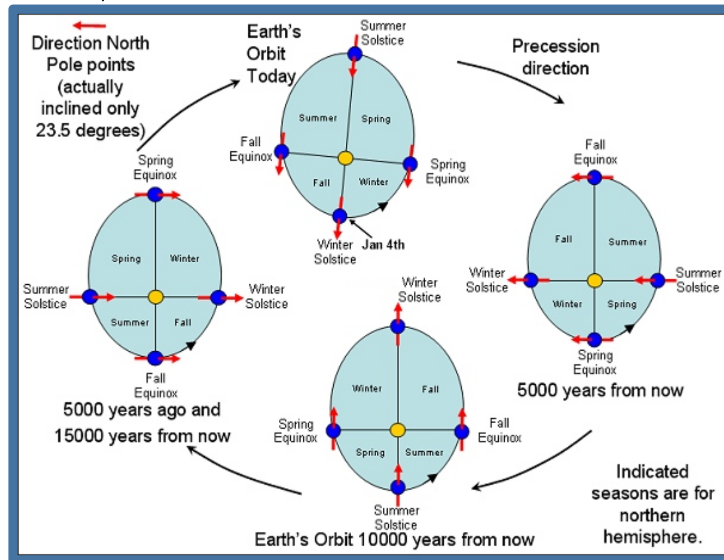
The Eccentricity of the earth's orbit is constantly changing, albeit at a slower rate.

$e = .01675104 - (.0000418)\, T - (1.26E\text{-}07)\, T^2$

FIGURE 17 THE PROXIMITY OF THE PERIHELION DURING THE GREAT PRECESSION CYCLE

The point where the Earth is closest to the Sun is called the *perihelion*. The point where the Earth is farthest from the Sun is called *aphelion*. To say that the equinox rotates clockwise around the orbit is the same as saying that perihelion falls later each year, and that after 21,000 years it drifts through the calendar once. We can sum up by saying that the solstices and equinoxes move along the orbit with period 21,000 years, but remains fixed in the calendar, while the perihelion stays fixed in the orbit, but progresses through the calendar with period 21,000 years.

The consequences of the Precession of the Perihelion is that the Perihelion will precess away from the vicinity of the Winter Solstice to the Summer Solstice , 10,000 years from now when the extremes of weather will be more severe than they are now. In addition to precession there is another factor involved in the behavior of the equinox drifts through the calendar once.



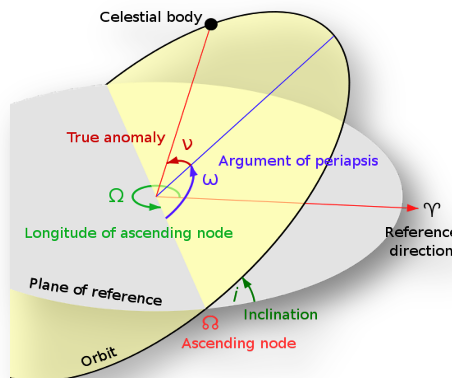
The **argument of periapsis or perihelion**

(or **argument of perifocus**) (ω) is the orbital element describing the angle of an orbiting body's periapsis (the point of closest approach to the central body), relative to its ascending node (the point where the body crosses the plane of reference from South to North). The angle is measured in the plane of the ecliptic and in the direction of motion. Adding the argument of periapsis to the longitude of the ascending node gives the longitude of the periapsis. Thus the longitude of perihelion will be 90^o when the Perihelion will be located at the Summer solstice. The Nirāyana year or Sidereal Year is the actual time required for the Earth to revolve once around the Sun with respect to a starting point on the ecliptic that is directly opposite a bright star called Chitrā (α Virginis, Spica).

It is the orbital period of Earth, equal to **365.256363604** mean Solar days **(31,558,149.760 seconds)**, that is **366.256363604** earth rotations or sidereal days. (A true cycle will always compare two objects that differ mathematically by exactly 1). It should not be confused with the Solar or Tropical Year which is defined as the time between 2 equinoxes or solstices. The sidereal year is 20^m 24^s longer than the tropical year. The longitude of Chitrā from this point is 180^0. The Indian Solar calendar is made to keep in phase with the Nirāyana year. See Figure 8 for the starting point of the Nirāyana year. In the year CE 285, the starting point of the Nirāyana year coincided with the March Equinox.

The celestial longitude, as measured from the March Equinox, of Chitrā was 179^o 59' 52'' at that time. For calendrical calculations, the longitude may be taken to be 180. Since the stars are fixed with respect to the ecliptic, the starting point remains unchanged. However, because of the Precession of the Equinoxes, the March Equinox recedes on the ecliptic westward each year and by 1 January 2001, it has shifted nearly **23^o 51'26''** from the starting point. Hence the Nirāyana year is really a sidereal year with mean length about **365^d 6^h 9^m 9.8^s (365.256363^d)**. This is about **20^m 26.88^s** longer than the mean length of the tropical year which is about **365^d 5^h 48^m $46^s.08$ (365.2422^d).** The Sun and the stars cannot be seen at the same time; if one looks every dawn at the eastern sky, the last stars seen appearing are not always the same. In a week or two an upward shift can be noted. As an example, in July in the Northern Hemisphere, Orion cannot be seen in the dawn sky, but in August it becomes visible. In a year, all the constellations rotate through the entire sky.

FIGURE 18 ELEMENTS OF AN ORBIT



THE SIDEREAL YEAR OR NIRĀYANA SAMVATSARA

The *sidereal year* is the actual time taken for the Earth to revolve once around the Sun with respect to the stars. The stars are fixed with respect to the elliptical orbit. As the Earth orbits the Sun, the apparent position of the Sun against the stars gradually moves along the ecliptic, passing through the twelve traditional constellations of the Zodiac, and returning to its starting point after one sidereal year. This motion is difficult to observe directly because the stars cannot be seen when the Sun is in the sky. However, if one looks regularly at the sky before dawn, the annual motion is very noticeable: the last stars seen to rise are not always the same, and within a week or two an upward shift can be noted. As an example, in July in the Northern Hemisphere, Orion cannot be seen in the dawn sky, but in August it becomes visible. If one

looks regularly at the sky before dawn, this motion is much more noticeable and easier to measure than the north/south shift of the sunrise point in the horizon, which defines the tropical year on which the **Gregorian** calendar is based. This is the reason many cultures started their year on the first day a particular special star, (Sirius, for instance), that could be seen in the East at dawn**.**

TABLE 5 MEASURES OF A YEAR,[75] OR SAMVATSARA (VARṢA)
327 and 51/67^d(Sidereal Lunar months) , there are 67 months in a 5 year cycle each of 27.31**66**^{d} duration, Nakṣatrika year (Vedic and Vedāṅga Jyotiṣa) or a Lunar Sidereal year
346.62^d a draconitic year.
353, 354 or 355^d — the lengths of common years in some Luni-solar calendars.
354.37^d Lunar year or Chandra Samvatsara(12 Lunar months, each comprising 29.53(29 32/62) days or 12/62 of a yuga) — the average length of a year in Lunar calendars
360^d Vedic Year, sometimes referred to as a Luni Solar year
365^d — a common year in many solar calendars.
365.2421988^d —**Saura Samvatsara**, a mean **solar tropical year** near the year 2000., mentioned in SūSi also known as Sāvana. The variation is 6.14e-7 per Julian century. Saura Varṣa or Ritu Varṣa or Solar year or Solar Tropical year
365.2424^d — a vernal equinox year.
365.2425^d — the average Gregorian year= 52.1775^w = 8,765.82^h = 525,949.2^m= 31,556,952^s (mean Solar, not SI). A common year is 365^d = 8,760^h= 525,600^m= 31,536,000^s. The 400-year cycle of the Gregorian calendar has **146,097^d(400 *365.2425**) and hence exactly **20,871^w**.
365.25^d — Julian Year, the average length of a year in the Julian calendar, exceeded the actual value by .0078 days in one year or about 8 days in a 1000 years
365.2563604^d — a Sidereal Solar year, mentioned in the Sūrya Siddhānta. Although this is the correct name for this quantity, the conventional usage is simply Sidereal Year.
A leap year is 366^d= 8,784^h = 527,040^m = 31,622,400^s.
383, 384 or 385^d — the lengths of leap years in some Luni-solar calendars.
383.9^d (13 Lunar months) — a leap year in some Luni-solar calendars.

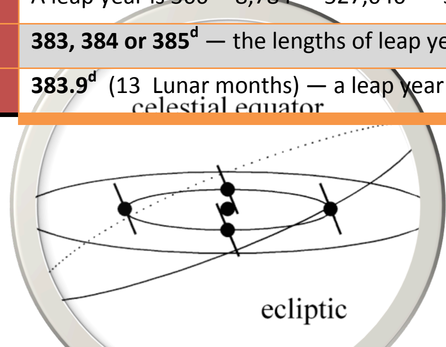


FIGURE 19 SHOWING INCLINATIONS OF AXES TO THE PLANE OF THE ECLIPTIC

Up to the time of the erroneous 'discovery' of the Americas and their misidentification as the Indies, at least in Europe, the years measured by the stars were thought to be exactly as long as the tropical years. In fact the measurement of the tropical year

was wrong. Many in Europe did not know that a tropical year is not an accurate measure of the year. Even then, in fact until the 16th century they had no accurate sidereal measurements in Europe. In fact, sidereal years are very slightly longer than tropical years. The difference manifests itself as the Precession of the equinoxes. One sidereal year is roughly equal to 1 + 1/25800 or 1.000039 tropical years. But until 1560 CE, when the Society of Jesus sent a whole slew of Jesuits trained to absorb such knowledge, in order that they may learn the science of the calendar and of navigation **from the Namboodri (etymology namma putri) Brāhmaṇas of Kerala, there was a lack of** knowledge of subjects like navigation. Prior to this date the Portuguese who were the most advanced in Europe, in these matters, only sailed during the night, when they had the visible stars to guide them. An average voyage to India took them 2 years from Lisbon. With the knowledge so gained (during ther prolongued stay in India) they fixed the **Gregorian** calendar in 1582 CE which was always error prone. There is absolutely no record of such a transmission which would have violated the Papal Bull.

JULIAN YEAR

Sosigenes of Alexandria was named by Pliny the Elder as the astronomer consulted by Julius Caesar for the design of the Julian calendar. It was Sosigenes who introduced the idea of an intercalated day and a leap year, every four years. The Julian year is exactly **365.25**^{d} of 86,400 SI seconds each, totaling 31,557,600 seconds. That is the average length of the year in the Julian calendar used in Western societies in previous centuries, and for which the unit is named. Nevertheless, because a Julian year measures duration rather than designates date, the Julian year does not correspond to years in the Julian calendar or any other calendar. Nor does it correspond to the many other ways of defining a year. The Julian Year was superseded by the Gregorian Year in October of 1582.

LUNI-SOLAR YEAR

The Luni-Solar year consists primarily of twelve lunations or Lunar months or 360 days, of which the present Sanskrit names, generally used in more or less corrupted forms, are Chaitra, Vaiśākhā et al, to Phālguna, as given above in connection with the Solar months. It is of two principal varieties, according as it begins with a certain day in the month Chaitra, or with the corresponding day in Karthikeya: the former variety is conveniently known as the Chaitradi year; the latter as the Kārttikadi year. For religious purposes the Lunar year begins with its first lunar day: for civil purposes it begins with its first civil day, the relation of which to the lunar day will be explained below. Owing to the manner in which, as we shall explain, the beginning of the Lunar year is always shifting backwards and forwards, it is not practicable to lay down any close Western equivalents for comparison: but an indication may be given as follows. The first civil day of the Chaitradi year is the day after the new-moon conjunction, which occurs next after the entrance of the Sun into Mīna, and it now falls from about 13 March to about 11 April: the first civil day of the Kārttikadi year is the first day after the new-moon conjunction which occurs next after the entrance of the Sun into Tula, and it now falls from about 17 October to about 15 November.

THE NUMBERING OF THE YEARS IN THE INDIC TRADITION

The epoch (starting point or first day of the first year) of the current era of Hindu calendar (both Solar and Luni-solar) is BCE 3101 February 17 on the Proleptic Julian calendar and on January 23 on the Proleptic Gregorian calendar (i.e. the Gregorian calendar extended back in time before its promulgation from 1582 October 15). Both the Solar and Luni-solar calendars started on this date. After that, each year is labeled by the number of years **elapsed** since the epoch.

This is a unique feature of the Hindu calendar. All other systems use the current ordinal number of the year as the year label. But just as a person's true age is measured by the number of years that have elapsed startingfrom the date of the person's birth, the Hindu calendar measures the number of years elapsed. Today (as of writing this on 2009-03--08) the elapsed years in the Hindu calendar are 5110 and this is the 5111th Hindu calendar year. Note that the Luni-solar calendar year will usually start earlier than the solar calendar year. Other systems of numbering the Hindu years were prevalent also.

THE USE OF A MAHĀYUGA AS A UNIT OF TIME FOR PLANETARY PERIODS

It was customary in ancient Indian astronomy to give the Bhagana or number of revolutions in a Mahāyuga of 4,320,000 sidereal years. The significance of using a Mahāyuga is explained in Chapter IV on the philosophy behind such a number. This is a unique feature of Indian Astronomy.

TABLE 6 PLANETARY REVOLUTIONS (BHAGANA) IN MAHĀYUGA OF 4,320,000 YEARS					
planet	Khandakhādhyaka	Sū-Sidd of Varāha	Modern Sū-Sidd 500CE)	Nilakanta	Āryabhaţīya
Moon N_m Sidereal revolutions	57,753,336	57,753,836	57,753,336	57,753,320	57,753,336
Sun N_s	4,320,000	4,320,000	4,320,000	4,320,000	4,320,000
Mars	2,296,824	2,296,824	2,296,832	2,296,864	2,296,824
Jupiter	364,220	364,240	364,220	364,180	364,224
Saturn	146,564	146,564	146,568	146,612	146,564
Moon's Apogee.	448,219	448,219	448,203	488,122	488219
Venus	7,022,388	7,022,388	7,022,376	7,022,268	70,22,338
Mercury	17,987,000	17,937,000	17,937,060	17,937,048	17,937,020
Moon's node	232,226	232,226	232,238	232,300	232,226
N_{cd} (Sāvana Dina or Sāvanāha)	1,577,917,800	1,577,917,800	1,577,917,828	1,577,917,500	1,577,917,800
N_{nd} sidereal days (Nakşatrika Dina)= $N_{cd} + N_s$	1,582,237,800	1,582,237,800	1,582,237,828	1,582,237,500	1,582,237,800
Lunations of the moon $=N_m - N_s$	53,433,336	53,433,836	53,433,336	53,433,200	53,433,336

The **month** is a unit of time, used with calendars, which is approximately as long as some natural period related to the motion of the Moon . The traditional concept arose with the cycle of Moon phases; such months (lunations) are synodic months and last approximately 2.53^d. From excavated tally sticks, researchers have deduced that people counted days in relation to the Moon 's phases as early as the Paleolithic conjunction age. Synodic months are still the basis of many calendars today. This period is called the *synodic* month from the Greek *synhodô* (σὺν ὁδῴ), meaning "with the way [of the Sun]" or in the same location as the Sun, a. Because of the perturbations of the orbits of the earth and Moon , the actual time between lunations may range from about **29.27^d** to about **29.83^d**. The long-term average duration is **29.53058181^d (29^d 12^h 44^m 2.8^s).** The actual length can vary up to 7 hours owing to Eccentricity of the Moon 's orbit and complicated interactions between the Earth, the Moon, and the Sun.

LUNAR OR SYNODIC MONTH OR CHANDRAMĀSA , THE PERIOD OF 1 LUNATION

TABLE 7 ORBITAL ELEMENTS OF THE MOON	
Orbital Characteristics	Value
Epoch	J2000
Average distance from earth	238,855 m (384,400 km)
Semi-major axes	384,400 km
Eccentricity	.055
Obliquity	5.15°
mean inclination of lunar equator to ecliptic	1.543°
distance at perigee	364,397 km
Apogee	251,970 km , 1.684323E-03AU
Distance at apogee	406731 km
period	656^h, 27.3217^d, $7.48015091E\text{-}02^y$
Sidereal months in a year	13.3687142^m
Average speed	29.783 km/s , 107,218 km/h
Equatorial diameter	2160 miles (3476 km)

The synodic month is used in the Indic calendars and other calendrical calculations such as those which use the incorrectly termed Metonic Cycle. Thus the lunar year based on a Lunar month would be equal to **29.53058181^d *12** or **354.3669817^d**. In other words, such a year would be short of a tropical year by about 11 days. But for societies that are not predominantly based on agriculture, such a lacuna would not be of great significance. It is perhaps for this reason that the Muslim calendar has chosen simplicity over temporal predictability when they decided to adopt the Lunar calendar. This is the reason why important events in a Muslim calendar like Ramzan do not occur at the same time or date of every year. The Muslim calendar is a Lunar calendar which makes no attempt at matching the periodicity of the Solar calendar and completely ignores the seasons of the year. The synodic month, the mean interval between conjunctions of the Moon and Sun, corresponds to the cycle of Lunar phases. The following expression for the synodic month is based on the Lunar theory of Chapront-Touze' and Chapront (2002)[77]:

$Month_{syn} = 29.5305888531 + 0.00000021621\,T - 3.64E\text{-}10\,T^2$ [days].

Again **T = (JD - 2451545.0)/36525** and JD is the Julian day number and T is the Julian century number from the J2000 epoch.

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Sauramāsa or Rāśimāsa are used in the Indian Calendar system and are determined by the date of the Saṃkrāṇti or the arrival of the Sun at the entry point of each of the 12 Solar Zodiacal constellations see for example Table 2, Chapter VI).

Sidereal Month, Nakṣatra Māsa - The period of the Moon 's orbit as defined with respect to the celestial sphere is known as a *sidereal* month because it is the time it takes the Moon to return to a given position among the stars (Latin: *sidus*): **27^d 7^h 43^m 11.6^s (27.3216615^d)** or in the Indian sexagesimal system Indian ephemeris , 2007)). As opposed to the Synodic or Lunar Month. The sidereal month is thus, about two day shorter than the Synodic month. Though the lunar time between two successive full Moon s is 29.53059 solar days, the time taken for Moon to go round the earth (sidereal month) is 27.32166^d. Another definition - The *sidereal month* is the time in which the Moon completes one revolution around the Earth and returns to the same position in the sky. However, the Moon has not completed a revolution around the Earth with respect to the Sun because during this time, the Earth and the Moon have also revolved about 27^o around the Sun and in order to line up between the Sun and the earth, the Moon must traverse approximately 2 more days (2* 13.333) to get there.

It is important to understand that for the purpose of a calendric theory, it does not matter whether we take a heliocentric or geocentric point of view. What matters is the quality of our tables. In fact, the first tables based on the Copernican system were worse than the old tables based on the Ptolemaic system. The motion of the Moon is very complex. The *synodic month* (or lunation) is the mean time from one new Moon (conjunction) to the next. The word synodic comes from the Greek word synhodos or meeting, referring to the Moon's conjunction with the Sun. Between 1000 BCE and 4000 CE it ranges from **29^d 6^h 26^m (29.27^d**) to **29^d 20^h 6^m (29.84^d)** with a mean of **29^d 12^h 44^m 3^s (29.53058818153^d)** .

DO THE ASTRONOMICAL CONSTANTS CHANGE WITH TIME

Most certainly they do. From these formulas we see that the cycles change slowly with time and the ancient Indic became aware of it, because of his long experience with observational astronomy. Furthermore, the formulas should not be considered to be absolute facts; they are the best approximations possible today. Therefore, a calendar year of an integral number of days cannot be perfectly synchronized to the tropical year. Approximate synchronization of calendar months with the lunar phases requires a complex sequence of months of 29 and 30 days. For convenience it is common to speak of a Lunar year of twelve synodic months, or 354.37056 days (29.5308181 *12). At the same time we also have a conceptual Solar month which is $1/12^{th}$ of a Solar year, comprising of **30.438229707^d**.

WEEK DAYS (VĀRA)

Vāsara, often abbreviated as *vāra* in Sanskrit-derived languages, refers to the days of the week, which are possibly of Sumerian/Babylonian origin, and bear striking similarities with the names in many cultures:

Following are the Hindi and English analogues in parentheses **Ravi** vāsara (*ravi-vāra* or ādi-vāra or Sunday; Ravi = sun) **Soma** vāsara (*some-vāra* or Monday; soma = moon), **Mangala** vāsara (*mangle-vāra* or Tuesday; Mangala = Mars), **Buddha** vāsara (*budh-vāra* or Wednesday; budh = Mercury),

Guru- Vāsara (*guru-vāra* or *Brhaspati-vāra* or Thursday; Brhaspati/guru = Jupiter)

Shukra-vāsara (*Shukra-vāra* or Friday; Shukra = Venus)

Shani-vāsara (*Shani-vāra* or Saturday; Shani = Saturn)

It is not clear when or where the concept of the Vāra started. Clearly the fact that it is mentioned in the Panchāngam indicates that it is at least as old as the Vedāṅga Jyotiṣa Period. It is definitely mentioned in the Sūrya Siddhānta, which is attributed to Asura Maya. The question remains as to the antiquity of the SS. We will address the historical aspects in chapter III more exhaustively.

TABLE 8 MEASURES OF A MONTH		
SUMMARY OF VARIOUS MEASURES OF A MONTH	SŪRYA SIDHANTA	MODERN VALUE
SOLAR MONTH,1/12TH OF A SOLAR YEAR OR CIVIL MONTH	30.438229707	30.438030
LUNAR MONTH OR SYNODIC MONTH CHANDRAMĀSA	29.530587946	29.530588
SIDEREAL MONTH, NAKṢATRA MĀSA	27.321673	27.32166156
LUNAR YEAR 12 LUNATIONS	354.36705535	354.367056
QUANTITY (SEXAGESIMAL SYSTEM)	D, H, M, S	D, H, M, S
MEAN SYNODIC MONTH	29,12,44, 2.79853	29 , 12, 44, 2.864
SIDEREAL MONTH	27,7, 44, 12.547	27 , 7, 43, 11.6
TROPICAL MONTH(EQUINOX TO EQUINOX)		27, 7, 43, 4.68
ANOMALISTIC MONTH(PERIGEE TO PERIGEE)		27, 18, 18, 37.44
NODICAL MONTH (NODE TO NODE)		27, 5, 5, 35.81
NUMBER OF LUNAR MONTHS (SYNODIC) $N_{lm} = N_m - N_s$	57,753,320-4,320,000= 53,433,320	57,752,984-4,320,000= 53,432,984
NUMBER OF INTERCALARY MONTHS ADHIKAMĀSAS $N_{am} = N_{sm} - N_{lm}$	1,593,320	1,593,320
NUMBER OF CIVIL DAYS IN A MAHAYUGA N_{sd} (SĀVANADINA)	1,577,917,500	1577907488
NUMBER OF LUNAR DAYS(TITHIS) IN A MY = $N_{lm} * 30 = N_{ld}$	1,602,999,600	1602989520.
OMITTED LUNAR DAYS = $N_{ld} - N_{sd} = N_k$ (KṢAYA-LOSS) KṢAYAYAHA	25,082,100	25,082,032

LEGEND FOR TABLE 8

N_{sm} = Number of Solar months

N_{sd} = number of civil days in a given period (e.g. Mahāyuga)

N_{ld} = number of lunar days (Tithi)

N_{am} = number of intercalary months

N_s = Number of revolutions of the sun (earth) in a given period of time

N_m = number of revolutions of the moon in a given period of time

N_{lm} = Number of lunar months in a given period of time

N_{lm} = Number of lunar months in a given period of time excluding intercalary months

AYANĀMŚA(ETYMOLOGY: AYANA "movement"+ AṂŚA "component") अयनाम्श

Also Ayanabhāga (Sk. *bhagana* "portion"), is the Sanskrit term in Indian astronomy for the cumulative amount of precession when referred to a prescribed epoch. This is the longitudinal difference between the Tropical (Sāyaṇa) and Sidereal (Nirāyana) zodiacs. Its importance stems from the fact that the longitude of an object in the sky, or the Right Ascension is measured from the Vernal equinox. The Vernal Equinox slips because of precession, and the Ayanāmśa is the amount by which it slips.

The Ayanāmśa is defined as the angle by which the sidereal ecliptic longitude of a celestial body is less than its tropical ecliptic longitude. The Ayanāmśa is mostly assumed to be close to being 24° today, according to N. C. Lahiri (Calendar Reform Committee, India (23.85° as of 2000). This value would correspond to a coincidence of the sidereal with the tropical zodiac in or near the year 293 CE, roughly compatible with the assumption that the tradition of the tropical zodiac as current in Western astronomy was presumably fixed by Ptolemy in the 2nd century, if we accept that Ptolemy compiled the version of the Almagest that is available to us (we discuss this in Chapters VIII & IX). In order for us to determine the Ayanāmśa for a given date we need therefore,

1. A reference epoch when the Sidereal and the Tropical longitudes are the same.
2. The rate of precession per year.

TABLE 9 SOME ASTRONOMIC 'CONSTANTS' VARIATIONS WITH TIME		
Quantity	Value, Symbol	Source
General Precession in Longitude	**5028. 796195" per Julian century. These are arc seconds and not seconds The (Astronomical Almanac, page K7 .**	
General Precession Rate variation with T	**50".290966+ 0".022226T- 0".000042 T^2**	
Mean Obliquity of the ecliptic	**23^o 26' 21."406 or** **23^o.438381 – 0^o.00000036** *d	
Eccentricity	**0.01670569 – 0.0000000012** *d	
Synodic month	**29.5305888531 + 0.00000021621 T - 3.64E-10 $T^{2\ d}$**	
d = JD – 2454100.5 (days of the year from 2007), T = (JD - 2451545.0)/36525(JD - 2451545.0)/36525, is the number of century years from 2000 CE		

To Determine *Ayanāmśa we need*
1. a reference epoch when the Sidereal and the Tropical longitudes are the same.
2. The rate of precession per year.

The sidereal (Nirāyana) ecliptic longitude of a celestial body is its longitude on the ecliptic defined with respect to the "fixed" stars. The tropical (Sāyaṇa) ecliptic longitude of a celestial body is its longitude on the ecliptic defined with respect to the vernal equinox point. Since the vernal equinox point precesses westwards at a rate of about 50".26 per year (the rate has been accelerating) with respect to the fixed stars, the longitude of a fixed body defined with respect to it will increase slowly. On the other hand, since the stars "do not move" (this ignores the effect of proper motion) the longitude of a fixed body defined with respect to them will never change. Table 8 compare the Surya Siddhānta with the modern value.

N_k = Number of Kshaya tithis in a given period.

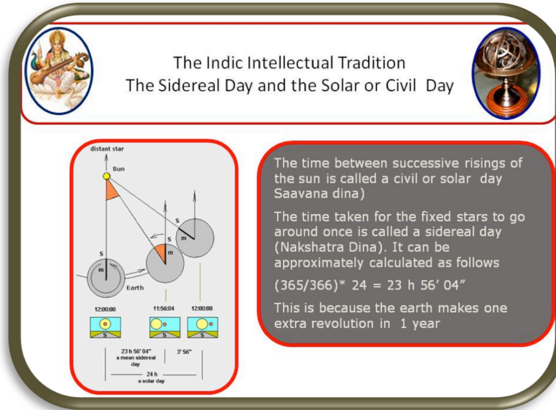


FIGURE 20 THE DIFFERENCE BETWEEN A SIDEREAL DAY AND SOLAR/CIVIL DAY

THE AYANĀMŚA The equation for the variation of the rate of precession with time is given by:

50".25747 +0" .02223T +0".0000026 T^2

(Where the epoch is taken as 1900 CE)

Where **T = (JD – 2415021.0)/36525** where the year is taken to be the Julian year.

Example: what is the rate of precession for February 22, 2010? JD = 2455250

T = 40229./36525 = 1.1041

gives Precession p = 5028 "·20345 per century correct to 3 decimal places. Correct value is 5028".796195. It is not uncommon to use a century as the population to find the expected value of the precessional rate, while at the same time, it is not too large a number to have picked up appreciable amounts of secular variation.

The equation for the the rate of precession with time is again given by;

50".290966 +0 ". 022226 T -0". 0000042 T^2 (where the epoch is taken as J2000)

Where **T = (JD - 2451545.0)/36525.** Where **T = (JD - 2451545.0)/36525.** Where the year is taken to be the Julian year. The epoch is Jan 1, 2000.

The Ayanāmśa (epoch 285 CE) or accumulated precession after epoch (can be obtained by integrating above with an initial value for epoch J2000;

23° 51´.25 532 + 5029".0966 T + 1 ".11161T^2 where T is in Julian centuries from J2000.

For example, on Feb 28, 2010, **T** = (2455256 – 2451545)/36525 = .101602

Ayanāmśa = 23° 59' 38".34.

There are many variations of these names in the regional languages, mostly using alternate names of the celestial bodies involved. The astonishing fact of the matter is that the system of dividing the week into 7 days is fairly widespread among all geographies and civilizations, and it is difficult to say when it originated. Again one must distinguish between a Solar day and a sidereal day. There is another unit that is used in India more so than in the Occident and that is the Pakṣa or fortnight. In India the fortnight is defined to be 15 days. The period when the moon is distancing itself from the Sun is called the Pūrva pakṣa or the Waning phase of the moon.

THE MEASURE OF A DAY

In modern spherical astronomy, the apparent westward motion of the celestial objects is known as the **Diurnal motion**. Strictly speaking diurnal means referring to the daytime as opposed to nocturnal (related to nighttime). By general usage, the daily revolution of the earth around its own axis in 24 hours is called the Diurnal Motion of the Earth.

It must be remembered that there was no knowledge of the diurnal rotation of the earth during the period we are referring to, namely the Vedic period, when we begin the recounting of our history and yet the ancients were able to measure the day by the rising of the Sun each day. The apparent motion of the celestial sphere and the objects in the sphere is also called the diurnal motion of the celestial objects, to be distinguished from the additional motions of the planets. In the Panchāngam there are measures of a 'civil day'. A week day is useful for daily routine to distinguish between various days within a seven day cycle. But it is not useful when longer periods of time are involved and hence do not get mentioned in the Rāmāyaṇa or MBH. A drawback of the weekday (regardless of whether it is a Gregorian calendar or an Indian Solar calendar), is the fact that that it begins at different times depending on location or longitude on the terrestrial sphere. It introduces an additional factor when one is interested in a specific time. One is forced to use an artificial measure such as Universal time, to avoid the ambiguity inherent in using a local time.

TABLE 10 MEASURES OF A DAY, SIDEREAL, SOLAR, CIVIL & LUNAR DAYS
1 Sidereal Day = 0.9972696246 Tropical Days
1 average lunar day or Tithi = 0.9852857143 civil days (solar)
Note that the Tithi is constantly varying about this mean value
24^h Sidereal Time = (24^h – 3′ 55.909″) Mean Solar Time
24^h Mean Solar Time = (24^h + 3′ 56.555″)Mean Sidereal Time

SIDEREAL DAY (NAKṢATRA DINA नक्षत्र दिन OR NAKṢATRĀHA नक्षत्राह OR ARKSHA DINA) AND SOLAR DAYS OR CIVIL DAYS (SĀVANA DINA OR SĀVANĀHA) सावननक्षत्रदिनमानम्

sāvana Nakṣatra dinamānam

The time taken between successive risings of the Sun or the time taken for one revolution is called a Solar or tropical day, also known as a civil day in India. The time taken for a fixed star to go around once is called a sidereal day.

The average length of a solar Day, gives the mean Solar Day or Madhyama Sāvanāha.
The difference is illustrated in Figure 21.

After T mean Solar days (or about **365.25** civil days, while the Sun would have made T revolutions, with reference to the fixed stars , the stars themselves would have completed T + 1 or 366.25 revolutions around the earth.

T mean Solar days = (T + 1) sidereal days, or 1 sidereal day = (T/T+1) ≅ 365.25/366.25 **civil days**
= 23^h 56 ' 4.1"

The equation for the mean sidereal time at Greenwich in degrees is
Θ_o = 100.460 618 37 + 36 000.770 053 608 T + 0.000 387 933 $T^2 – T^3$/38 710 000
in units of RA, hours, minutes, and seconds
$\Theta_o = 6^h\ 41^m\ 50^s.54841$+ 8640 184^s 812 866 T + 0^s.093 104 T^2 – 0^s.000 0062 T^3
Where T **= T = (JD - 2451545.0)/36525** centuries since epoch

To obtain the sidereal time θ_o at any time other than 0^h UT, multiply that instant by 1.002 737 909 35 and add the result to the sidereal time Θo. UT and Greenwich mean sidereal time agree at one instant of time every year at the autumnal equinox (around September 22nd. Thereafter, the difference between them grows in the sense that ST runs faster than UT, until exactly half a year later it is 12 hours.
After 1 year, the times again will agree after 24 hours. In a MY, the number of civil days is the number of sunrises that take place in the given period. Similarly, the number of sidereal days is equal to the number of star rises that take place in the same period. The reason is that the Sun has shifted approximately by 1^o (.985626) while the earth has made 1 complete revolution around its axis. The stars do not make any such relative motion, so that by the end of 1 year, the number of sidereal days will be greater than the number of civil days by exactly one unit.

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THE NUMBER OF CIVIL DAYS, YUGASĀVANĀDINĀDIH
SIDEREAL DAYS = CIVIL DAYS + NUMBER OF REVOLUTIONS OF THE SUN
(OR THE EARTH AROUND THE SUN) = 1577917500 + 4320000 = 1582237500 OR
CIVIL DAYS = SIDEREAL DAYS – NUMBER OF PLANETARY (EARTH) REVOLUTIONS.
In a MY, by definition, the number of sunrises is equal to the number of civil days in the same period. This relation is not only valid for the Sun but is also true for all the planets of the Sun.

NUMBER OF PLANET RISINGS = SIDEREAL DAYS – NUMBER OF REVOLUTIONS OF PLANET.

The solar year can be further divided into 360 equal parts to give us another definition of a Solar Day or A Saurāha. This is a definition that is ambiguous with that given for the Sāvana dinaha. However, this is rarely used, so we will continue to use the Solar Day to mean the Tropical day or Sāvana dinaha.

THE TITHI - तिथि A LUNAR DAY (CHANDRĀHAS)

The Lunar month is divided into 30 Tithis, thus each fortnight is divided each into fifteen Tithis or Lunar days. On the New Moon day - that is Amāvāsyā - the distance between the Sun and Moon is only zero (0) degrees and at that time the Moon will have no light. On the full Moon day the distance is 180 degree as both Sun and Moon are on opposite positions. So, that when the distance between Sun and Moon is 0 - 12 degrees that is defined as Pādyami, and when it is 12-24 degrees that is defined as Vidiya (2nd day) and when the distance is 24-36 degrees that day is defined as Tadiya (third day). According to the Indian calendar *or Panchāngam, Tithi* is a lunar date based on the rotation of the Moon around the earth, and is one of the five important aspects of an Indian almanac (*Panchāngam – Pancha* means five and *anga* means parts).

The Tithi is the time in which the Moon increases or decreases her distance from the Sun round the circle by twelve degrees; and the almanacs show each Tithi by its ending-time; that is, by the moment, expressed in ghatikas and galas, after sunrise , at which the Moon completes that distance. In accordance with that, the Tithi is usually used and cited with the weekday on which it ends; but there are special rules regarding certain rites and festivals, which sometimes require the Tithi to be used and cited with the weekday on which it begins or is current at a particular time. The first Tithi of each fortnight begins immediately after the moment of new-moon and full-moon respectively; the last Tithi ends at the moment of full-moon and new-moon. The Tithis are primarily denoted by the numbers I, 2, 3, etc., for each fortnight; but, while the full-moon Tithi is always numbered 15, the new-moon Tithi is generally numbered 30, even where the Pūrnimanta month is used. The Tithis may be cited either by their figures or by the Sanskrit ordinal words prathama, "first," dvitiya," second," etc., or corruptions of them. But usually the first Tithi of either fortnight is cited by the term pratipada, and the new-moon and full moon Tithis are cited by the terms Amāvāsyā and Pūrnima; or here, again, corruptions of the Sanskrit terms are used and special names are sometimes prefixed to the numbers of the Tithis, according to the rites, and festivals, prescribed for them, or events or merits assigned to them: for instance, Vaiśākhā śukla 3 is Akṣaya or Akṣaya-tritīya the third Tithi which ensures permanence to acts performed on it; **Bhādrapadā** Sukla 4 is Ganesa-chaturthi, the fourth Tithi dedicated to the worship of the god Ganesha, Ganapati, and the Amanta **Bhādrapadā** or Pūrnimanta Aśvina Kṛṣṇa 13 is Kaliyugadi-trayodasi, as being regarded (for some reason which is not apparent) as the anniversary of the beginning of the Kaliyuga, the present Age. The first Tithi of the year is styled Samvatsara-pratipada, which term answers closely to our "New Year's Day." The civil days of the Lunar month begin, like those of the Solar month, at sunrise, and bear in the same way the names of the weekdays. But they are numbered in a different manner; i.e. fortnight by fortnight and according to the Tithis. The general rule is that the civil day takes the number of the Tithi which is current at its sunrise.
As the motions of the Sun and the Moon vary periodically, a Tithi is of variable length, ranging, according to the Hindu calculations, from $21^h\ 34^m\ 24^s$ to $26^h\ 6^m\ 24^s$; it may, therefore, be either shorter or longer than a civil day, the duration of which is practically 24^h (one minute, roughly, more or less, according to the time of the year). A Tithi may end at any moment during the civil day; and ordinarily it ends on the civil day after that on which it begins, and covers only one sunrise and gives its number to the day on which it ends.

KṚṢṆA PAKṢA AND ŚUKLA PAKṢA

The Tithi is divided into two karanas; each karana being the time in which the Moon increases her distance from the Sun by six degrees. But this is a detail of astrological rather than chronological interest. So, also, are two other details to which a prominent place is given in the Lunar calendyoga, or time in which the joint motion in longitude, the sum of the motions of the Sun and the Moon, is increased by $13^{o}20'$; and the Nakṣatra, the position of the Moon as referred to the ecliptic by means of the stars and groups of stars which have been mentioned above under the Lunar month.

Most of the Indian social and religious festivals are celebrated on a date corresponding to the original *Tithi*. The distance between the Sun and the Moon calculated on a daily basis is used to denote Tithi. The positioning and the movements of both Sun and Moon are different (the Sun is much farther away than the Moon), and hence it does not make sense to refer to the distance in terms of Miles are meters but in degrees only. As the orbit of the Moon comprises 360^{o} and there are 30^{d} (^{or} Tithis) in a month, each Tithi occupies 12^{o} (360/30) of the Zodiac, measured as the difference between the longitudes of the Sun and the moon. The 2 Pakṣas, and Śukla together constitute 30 Tithis, and form a Chandramāsa or a Lunar month (see, chapter VI). There is another specific artifact to be noted: the movements of the Sun are slow while the corresponding movements of the Moon are relatively rapid. If one takes the average motion (mean motion) of the Sun, it traverses $59.1'$($1^{o} = 60'$) in a day, whereas the Moon 's mean motion is about 790.56^{m}, the difference between the Sun and Moon 's motion is 790.56 - 59.1 = 731.46^{m} that is equal to 12.19^{o} but for ease of calculation the Indics have chosen 12^{o}.

To gain the correct Tithi, one should not use the mean motions – it is critical to use the accurate positions obtain the right time of Tithi, using the appropriate algorithms. In a month there are 30 Tithis- and on an average each Tithi will run for 23.62^{h}. But, in many days, the Tithi usually hovering between 20^{h} to 26.40^{h} - and with these huge fluctuations, one cannot depend upon the mean motions and this fluctuation occurs because of the daily changes in the motion of the Moon. The motion of the Moon in reality traces a far more complex pattern, than the ellipse which is the consequence of Kepler's Law. In the Hindu belief system, the accurate timing of the performance of a particular aspect of a Pūja associated with a variety of rites and ceremonies is essential for the proper performance of the Pūja. Such an injunction was a corollary to the assumptions made in the belief system prevalent during the ancient era. Hence the need for precision.

Once the concept of the civil day was put into use, it became clear, that this was the unit of time that was subject to a minimum of ambiguity, whenever the need arose to determine the difference in time between 2 events. The algorithm to determine the Ahargaṇa was an essential step prior to computing the positions of the planets and is a ubiquitous subroutine in most calendrical calculations. The drawback of using a quantity such as the Ahargaṇa, was that the resulting numbers could be huge, and would necessitate facility with the arithmetic of large numbers and presupposes the existence of a place value system, which is the reason why the Greek avoided counting days from a fixed point in time, preferring instead to use the regnal period of the Archon. Clearly that does not solve the problem of maintaining an accurate absolute chronology using only integers. This was not a stumbling block for the ancient Hindu since he developed the decimal place value system, but it was a major impediment to the Greeks who had no such facility. As mentioned in the prolog, it was not until 1582 that Josephus Justus Scaliger developed the notion of the Julian Day count, which is in reality a concept that was inherent in the Ahargaṇa. It is the absence of such simple concepts, simple by today's standards that contributed to the lack of progress for almost 1200 years.

The term **Ahargaṇa** literally translates into a 'heap of days'. It is a positive integer that gives the number of civil days that have elapsed since a given epoch, till the date on which the Ahargaṇa needs to be determined. It has been customary since the time of the ancients to choose the date of the Kaliyuga, as

the epoch. The choice of the epoch is determined by proximity to the beginning of a kalpa or the beginning of a Yuga, or any date for which the positions of the planets are already known. The method of computation of the Ahargaṇa is given in several classical texts as well as in the Siddhāntic literature.

AHARGAṆA अहर्गण (DYUGANA, DINARĀŚI)

We give below a ty pical algorithm for the calculation of an AHARGAṆA

Convert the tropical years elapsed since epoch into Lunar months

Add the number of Adhikamāsas during this period to give the actual number of Lunar months elapsed, till the beginning of the given year

Add the number of Lunar months elapsed in the given (partial) year

Convert these actually elapsed Lunar months into Tithis by multiplying by 30

Add the elapsed number of Tithis in the current Lunar month

Convert the elapsed number of Tithis into civil days.

Let Np represent the number of lunar years that had elapsed since the beginning of Kaliyuga and Nq represent the number of lunar months that had elapsed since the beginning of the current lunar year;

$N'_{lm} = 12\ N_p + N_q$ .... (1)

Represents the Number of Lunar months since the beginning of KY, excluding the number of Adhimāsa till the desired date. Using proportionality with the number in a KY

Using proportionality

$N_{am} = (159320 * N'_{lm}) / 5184000$ .... (2)

See table 6 Measures of a month

The number of Lunar months $\boldsymbol{N_{lm} = N'_{lm} + N_{am}}$ .... (3)

To obtain the number of Tithis, first calculate

N_{ld} =total number of Tithis, lunar days $= N_{lm} \times 30 + N_s$ .... (4)

To subtract the number of Kshaya Tithis, calculate using proportionality with known numbers in a KY

$N_k = N_{ld} \left(\frac{25082100}{160299600} \right)$ .... (5)

See table 7, Measures of a month

Then the Number of Civil days elapsed since the beginning of Kaliyuga or Ahargaṇa

$N_{cd} = N_{ld} - N_k$ .... (6)

JULIAN DAY NUMBER (JD)

The Julian Day Number for a given date is a count of days commencing on January 1, 4713 BCE. The concept was enunciated by Josephus Justus Scaliger in 1582, the year that the Gregorian Colander reform was promulgated. There is suspicion that the sudden appearance of this quantity had to do with the knowledge gained by the Jesuits in Malabar, when they were sent there under the leadership of Matteo Ricci by Christopher Clavius, to learn the intricacies of the Indian Jyotiṣa. There is no mention of such a concept prior to the enunciation by Scaliger. It is clear that even Ptolemy did not use such a concept when determining the difference between two dates. He preferred to transfer a Roman date (which only listed the year of the reign of the current emperor, necessitating another calendar which

listed all the Kings and dynasties, see for instance) to the Egyptian calendar, when calculating differences, because of the simplicity of the Egyptian calendar and the fact that it remained unchanged for an extremely long period of time. For example, suppose we were asked to determine the difference in number of days between January 1, 2000 and January 20, 2010.

The JD for January 1, 2000 = 245 1544
The JD for January 20, 2010 = 245 5217
Difference = 3673

SIZE AND DISTANCE OF CELESTIAL OBJECTS

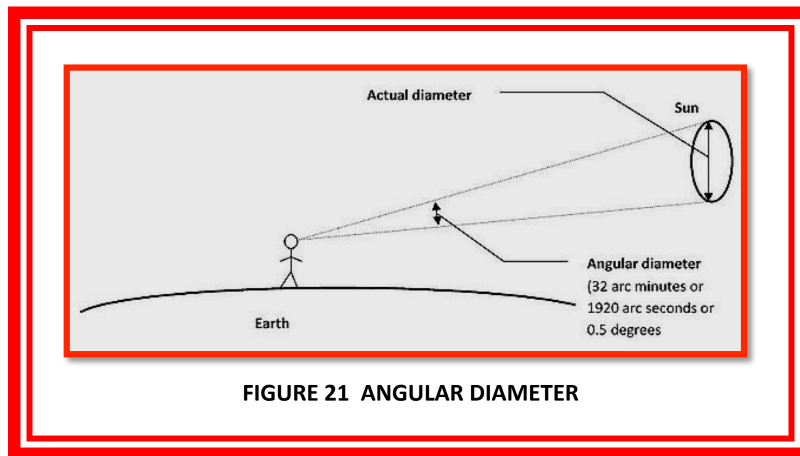


FIGURE 21 ANGULAR DIAMETER

We have not said a whole lot about the size and distance of objects in the sky. The concept of the celestial sphere ignores the distance of the star, as the primary concern of the ancient astronomer was to pinpoint the location of the Sun, the Moon, and the planets. It is in this context that the notion of angular diameter comes in handy. Objects with the same angular diameter tend to appear similar in size, the most prominent example for this being the Sun and the Moon as can be seen from the table below, the angular diameter of the Sun and the Moon are roughly equal although their actual sizes are quite different . This explains why the Sun and the Moon appear to be of the same size in the sky.

The ancients did know how to compute the distance of objects in the celestial sphere, and assigned a special place for the number 108, which as we know is the ratio of the distance to the diameter of the sun, and since we know the angular diameters are approximately the same for the Sun and the Moon, this ratio must hold for the Moon also. It is not difficult to compute this number. The angular measurement of the Sun can be done during an eclipse. Similarly for the moon, it can be done on a clear full moon night. An easy check on this measurement can be carried out by holding a pole at a distance 108 times its length. Nevertheless, this would require careful measurements in order to arrive at the

mean number of 108. The reason that the ancients settled on 108 as the mean number even though they were aware that it was not the exact number, is because it factors into 27*4, which is also the reason they chose to settle on 27 Nakṣatras after experimenting with 28. This bespeaks a knowledge of the principles of simulation, and that they had realized the value of Einstein's admonition to 'Keep it simple but no simpler".

TABLE 11 ANGULAR DIAMETERS			
Sun	31.6′ – 32.7′	**Mercury**	5″ – 13″
Moon	29.3′ – 34.1′	**Uranus**	3″ – 4″
Venus	10″ – 66″	**Neptune**	2″
Jupiter	30″ – 49″	**Ceres**	0.8″
Saturn	15″ – 20″	**Pluto**	0.1″
Mars	4″ – 25″	**R Doradus**	0.052″ – 0.062″

The angular diameter of an object can be calculated using the formula:
$\delta = 2 \arctan (d/2D)$ in which δ is the angular diameter, and *d* and *D* are the visual diameter of and the distance to the object, expressed in the same units. When *D* is much larger than *d*, δ may be approximated by the formula $\delta = d / D$, in which the result is in radians.
For a spherical object whose *actual* diameter equals d_{act}, the angular diameter can be found with the formula: $\delta = 2 \arcsin (d_{act}/2D)$. For practical use, the distinction between *d* and d_{act} only makes a difference for spherical objects that are relatively close. In astronomy the sizes of objects in the sky are often given in terms of their angular diameter as seen from Earth, rather than their actual sizes. The angular diameter of Earth's orbit around the Sun, from a distance of one parsec, is 2″ (two arc-seconds). The angular diameter of the Sun, from a distance of one light-year, is 0.03″, and that of the Earth 0.0003″. The angular diameter 0.03″ of the Sun given above is approximately the same as that of a person at a distance of the diameter of the Earth.

Table 11 shows the angular sizes of noteworthy celestial bodies as seen from the Earth.
Angular diameter : the angle subtended by an object (for a given distance, this is the size of the object. Interestingly but not surprisingly, Venus can look bigger than Jupiter during parts of its orbit from the above table, It is clear that the angular diameter of Sun, when seen from Earth is approximately 32 arc-minutes, i.e., 1920 arc-seconds or simply 0.53^{o}. The picture which is given here, best explains the phenomena. The angular diameter of the Sun is ca. 250,000 that of Sirius (Sirius has twice the diameter and its distance is 500,000 times as much). The angular diameter of the Sun is also ca. 250,000 that of α Centauri A (it has the same diameter and the distance is 250,000 times as much; the Sun is 40,000,000,000 times as bright, corresponding to an angular diameter ratio of 200,000, so α Centauri A is a little brighter per unit solid angle). The angular diameter of the Sun is about the same as that of the Moon (the diameter is 400 times as large and so is the distance.

While angular sizes measured in degrees are useful for larger patches of sky (in the constellation of Orion, for example, the three stars of the belt cover about 3 degrees of angular size), we need much finer units when talking about the angular size of galaxies, nebulae or other objects of the night sky.

Degrees, therefore, are subdivided as follows
360 degrees (°) in a full circle

60 arc-minutes (′) in one degree
60 arc-seconds (″) in one arc-minute

To put this in perspective, the full Moon viewed from earth is about ½ degree, or 30 arc minutes (or 1800 arc-seconds). The Moon's motion across the sky can be measured in angular size: approximately 15 degrees every hour, or 15 arc-seconds per second. A one-mile-long line painted on the face of the Moon would appear to us to be about one arc-second in length.

In astronomy, it is typically difficult to directly measure the distance to an object. But the object may have a known physical size (perhaps it is similar to a closer object with known distance) and a measurable angular diameter. In that case, the angular diameter formula can be inverted to yield the Angular diameter to distant objects as **d = D tan (δ/2).**

In non-Euclidean space, such as our expanding universe, the angular diameter distance is only one of several definitions of distance, so that there can be different "distances" to the same object.

The ***Alfonsine tables*** (sometimes spelled ***Alphonsine tables***) were ephemerides (astronomical tables that show the position of the Sun, Moon and planets relative to the fixed stars) drawn up at Toledo by order of Alfonso X around 1252 to 1270. Alfonso X assembled a team of scholars including both Jews and Moors to produce a new ephemeris that corrected anomalies in the Tables of Toledo. They were able to exploit Arabic astronomical discoveries as well as earlier astronomical works preserved by Islamic scholars. New observations were used to augment these sources. The Alfonsine tables were originally written in the Castilian form of Spanish but became better known when they were later translated into Latin by Georg von Peuerbach used the *Alfonsine tables* for his astronomy book, *Theoricae novae planetarum* (*New Theory of the Planets*). The first printed edition appeared in 1483. The primary use of these and similar tables was to help in the construction of horoscopes by astrologers.

The methods of Claudius Ptolemy were used to compute the table and they divided the year into **365^d 5^h 49^m 16^s**; very close to the currently accepted figure. There is a famous (but apocryphal) quote attributed to Alfonso upon hearing an explanation of the extremely complicated mathematics required to demonstrate Ptolemy's geocentric model of the Solar system - "**If the Lord Almighty had consulted me before embarking on creation thus, I should have recommended something simpler**." (The validity of this quotation is questioned by some historians.) This quotation has been used to illustrate the large number of additional epicycles introduced into the Ptolemaic system in an attempt to make it conform to observation.

However, modern computations have concluded that the methodology used to derive the Alfonsine tables was Ptolemy's unmodified theory and that the original computations were correct. The puzzling aspect to this is why the Julian calendar was not fixed when Ptolemy's calculations were available in the 2nd century CE.

Since all the planets are continuously moving in their orbits around the Sun, there will occur opportunities when they will not only conjunct with each other but also with the Sun. The planet will then no longer be visible as long as it is in conjunction with the Sun.

HELIACAL RISING OF STARS

When the planet first becomes invisible because it conjuncts with the Sun, it is known as Heliacal Setting. Similarly, when it first becomes visible as it moves away from total conjunction it is recognized

as the Heliacal Rising of the star. The Heliacal Rising of a star (or other body such as the Moon), a planet or a constellation occurs therefore. When it first becomes visible above the eastern horizon at dawn, after a period when it was hidden below the horizon or when it was just above the horizon but hidden by the brightness of the Sun.

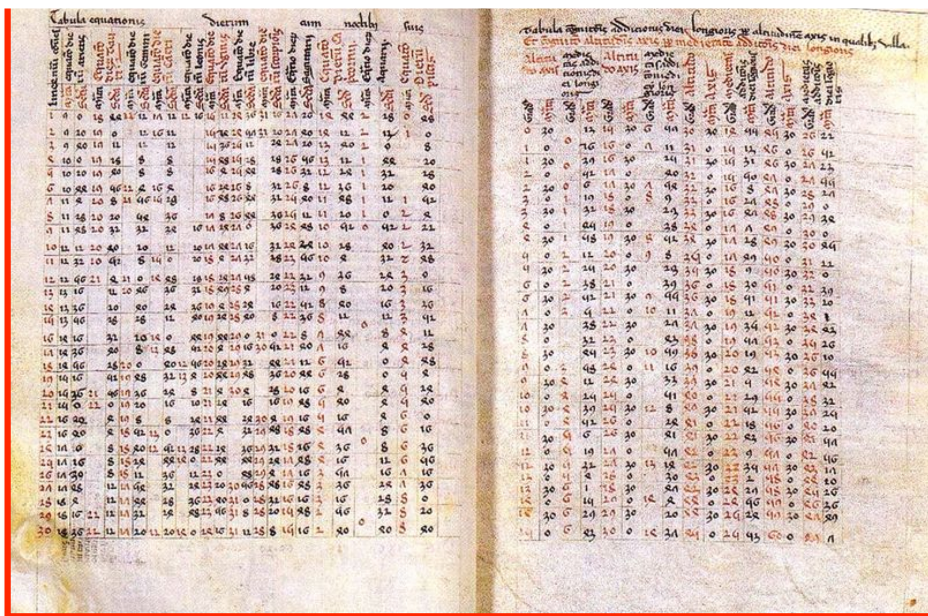
Each day after the heliacal rising, the star will appear to rise slightly earlier and remain in the sky longer before it is hidden by the Sun (the Sun appears to drift eastward relative to the stars along a path called the ecliptic). Eventually the star will no longer be visible in the sky at dawn because it has already set below the western horizon. This is called the *acronychal setting*. A star will reappear in the eastern sky at dawn approximately one year after its previous heliacal rising. Because the heliacal rising depends on the observation of the object, its exact timing can be dependent on weather conditions.

Not all stars have heliacal risings; some may (depending on the latitude of observation on the earth) remain permanently above the horizon, making them always visible in the sky at dawn, before they are hidden by the brightness of the Sun; others may never be visible at all (like the North Star in Australia).

Constellations containing stars that rise and set were incorporated into early calendars or Zodiacs. The ancient Egyptians based their calendar on the heliacal rising of Sirius and devised a method of telling the time at night based on the heliacal risings of 36 stars called decan stars (one for each 10° segment of the 360° circle of the Zodiac/calendar). The Sumerians, the Babylonians, and the ancient Greeks also used the heliacal risings of various stars for the timing of agricultural activities. To the Māori of New Zealand, the Pleiades are called Matariki and their heliacal rising signifies the beginning of the New Year (around June). Hayashi (2008) writes 'Planetary longitudes, heliacal rising and setting of the planets, conjunctions among the planets and stars, Solar and Lunar eclipses, and the phases of the Moon are among the topics Bhāskara discusses in his astronomical treatises [78]. Bhāskara I's works were followed by Vateśvara (880 CE), who in his eight chapter *Vateśvara Siddhānta* devised methods for determining the parallax in longitude directly, the motion of the equinoxes and the solstices, and the quadrant of the Sun at any given time.

FIGURE 22 ALFONSINE TABLES

[78] Hayashi, Takao (2008), Brahmagupta, Encyclopedia Britannica.



WHY DID THE INDICS USE SIDEREAL MEASUREMENTS ?

The simple answer to this is that because this yields the true value. We are indebted to Isaac Newton and his contemporaries for enunciating a major concept that revolutionized the science of mechanics, namely the notion of the Inertial frame of reference. We do not wish to go into a discussion on this topic as it would take us into the realm of mechanics[79], but, an inertial frame of reference is a necessary condition to arrive at the proper equations of motion of a dynamical system. As an example, a reference frame need not be stationary in order to be an inertial frame of reference. It can be one where the origin is moving at a constant linear velocity. Neither an accelerating reference frame nor a rotating reference frame, would qualify as an inertial reference frame. The upshot of this is that a reference frame centered in the Sun cannot be an inertial frame, since the Sun is itself a rotating body rotating around the Galactic center. The IAU has now come up with a quasi inertial reference frame.

We see no evidence that the ancient Indics had knowledge of celestial mechanics and the inertial frame of reference is only of significance when we are considering the dynamics of the problem, but they were on the right track when they insisted that their measurements include sidereal data with respect to a distant star. We have already defined the notion of a fixed star. By the same token, to a high degree of accuracy, a fixed star with a minimum of proper motion can serve as an inertial frame of reference. When comparing values with results from a program using celestial mechanics, sidereal measurements are therefore the appropriate measure to use. In fact it makes little sense to argue otherwise.

Although the Indics were aware of the phenomenon of Precession of the equinoxes (Hipparchus is supposed to have known about Precession but the claim is unverifiable), the right physical explanation for Precession eluded them. The Indics came up with the value of 54^{o} (which is of by about 7%). Ptolemy uses the value of 34^{o} which is not even in the ball park. It was **Nasir al Din al Tūsi (see Table 5, chapter VIII)** who came close to the currently accepted value of 50.29^{o}. There is circumstantial evidence that The Vedics were aware of Precession (see chapter III) but that knowledge does not appear to have survived

[79] The history of Mechanics, comprising as it does the more mature branches of Physics is a fascinating story in its own right and it needs to be told in a manner that is appreciated by those who are not Scientists or Engineers.

to the VJ era

EQUATION OF THE CENTER (MAṆDAPHALA, मण्डफल, MAṆDOCCAPHALA)

The ancients, as we have seen, assumed to a first approximation that the motion of the heavenly bodies took place in circles and that the planet moved with a constant angular velocity. To account for the fact that the motion is in an elliptical orbit, one can define the equation of the center, which is the difference between the true position and the mean position of the planet calculated using circular orbits or what is also referred to as the Anomaly[80].

The **equation of the center**, in astronomy and elliptical motion, is equal to the true anomaly minus the mean anomaly, $\lambda_t - \lambda_m$ i.e. the difference between the actual angular position in the elliptical orbit and the position the orbiting body would have if its angular motion was uniform. It arises from the ellipticity of the orbit, is zero at pericenter and apocenter, and reaches its greatest amount nearly midway between these points.

For small values of orbital Eccentricity, *e*, the true anomaly, λ_t, may be expressed as a sine series of the mean anomaly, λ_m. The following shows the series expanded to terms of the order of e^5 for the true anomaly:

$$\lambda_t = \lambda_m + \left(2e - \frac{1}{4}e^3 + \frac{5}{96}e^5\right)\sin\lambda_m + \left(\frac{5}{4}e^2 - \frac{11}{24}e^4\right)\sin 2\lambda_m + \left(\frac{13}{12}e^3 - \frac{43}{64}e^5\right)\sin 3\lambda_m +$$

$$\frac{103}{96}e^4\sin 4\lambda_m + \frac{1097}{960}e^5\sin 5\lambda_m + O(e^6) \ldots\ldots (7)$$

Related expansions may be used to express the true distance *r* of the orbiting body from the central body as a fraction of the semi-major axis *a* of the ellipse,

$$\frac{r}{a} = (1 + e^2/2) - \left(e - \frac{3}{8}e^3\right)\cos\lambda_m - \frac{1}{2}e^2\cos 2\lambda_m - \frac{3}{8}e^3\cos 3\lambda_m - O(e^4) \ldots\ldots (8)$$

or the inverse of this distance *a* / *r* has sometimes been used (e.g. it is proportional to the horizontal parallax of the orbiting body as seen from the central body):

$$\frac{a}{r} = 1 + (e - e^3/8)\cos\lambda_m + e^2\cos 2\lambda_m + \frac{9}{8}e^3\cos 3\lambda_m + O(e^4) \ldots\ldots (9)$$

Series such as these can be used as part of the preparation of approximate tables of motion of astronomical objects, such as that of the moon around the earth, or the earth or other planets around the sun, when perturbations of the motion are included as well.

JUPITER'S EQUATION OF THE CENTER

The above when instantiated for the case of Jupiter (e = .048254), see table 4, chapter VIII) gives the following expression for the equation of the center

$\lambda_t = \lambda_m + .0964799 \sin\lambda_m + 0.0029081 \text{ SIN } 2\lambda_m + 0.0001218 \sin 3\lambda m + 0.0000058 \sin 4\lambda_m$.

If we had neglected higher degree term in e, this expression would have reduced to equation 10 for the general case

$\boldsymbol{\lambda_t = \lambda_m + 2e \sin\lambda_m}$ ....(10) for very low eccentricities, less than, e =.02

See eqn.28 in Chapter VIII

$\lambda_t = \lambda_m + .096508 \sin\lambda_m$ ....(11)

---

[80] *Anomaly means inequality, as in the simple case of an eccentric orbit, without an epicycle, it is the angle traversed by the radius vector, since it began its journey at the Apogee*

For the case of Jupiter, the RADIUS OF THE EPICYCLE AS a proportion of the radius of the main orbital circle.) Hipparchus' estimates, based on his data as corrected by Ptolemy yield a figure close to 5.81°

Most of the discrepancy between the Hipparchan estimates and the modern value of the equation of the center arises because Hipparchus' data were taken from positions of the Moon at times of eclipses[82]. He did not recognize the perturbation now called the **evection**. At new and full moons the evection opposes the equation of the center, to the extent of the coefficient of the evection, **4586.45**". The Hipparchus parameter for the relative size of the Moon's epicycle corresponds quite closely to the difference between the two modern coefficients, of the equation of the center, and of the evection (difference **18053.1",** about **5.01°).** Apart from measurements at specific locations it is now recognized that the moon's orbital path cannot be modeled on the basis of a two body problem in celestial mechanics, because of the gravitational pull of the Sun on the Moon. Manjula described the term causing evection and Bhāskara II described the term that signifies Variation. A simplified theory is available in the book by Jean Meeus. This needs to be compared to the work of Manjula (evection) and Bhāskara II to see if the Indians were able to model this accurately. This is beyond the scope of what we set out to do in this volume.

PLANETARY SIDEREAL PERIODS

The following formula gives the Sidereal Period of a planet other than earth $\frac{1}{Y} = \frac{1}{S} - \frac{1}{P}$, where Y stands for mean solar days in a solar year and P is the sidereal period of the planet, and S is the synodic period of the planet.

Thus for Jupiter S the synodic period is 398.88(Table 11, chapter VI). Therefore,
$\frac{1}{P} = \frac{1}{398.88} - \frac{1}{365.256363} = 1/4333.067^{d}$, therefore **,**

P = 4333.067^{d} = 11.86308^{y}.

FIGURE 23 SIDEREAL VS SYNODIC ORBITAL

It can also be written as **P =** $\frac{SY}{S-Y}$**.**

Figure 24 shows the Kinematics of the relative motions of the Outer Planet, the Earth, and the Sun.

CD is the portion of the orbit between 2 oppositions of the outer planet. The dashed blue curve shows the Earths complete orbit.

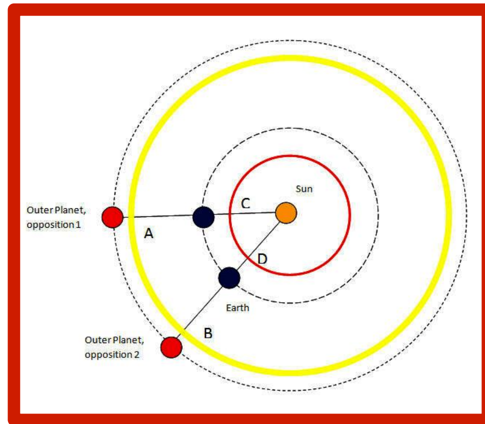
AB is the orbit between 2 synodic oppositions. From the geometry of the picture we can tell that the angle swept out by the outer planet is also the angle swept out by the earth after making 1 revolution.
Thus $\frac{P}{S} = \frac{Y}{S-Y}$.

---

[81] *Brown, E.W. Tables of the Motion of the Moon. Yale University Press, New Haven CT, 1919.*
[82] *ONHAMA, pp.315-319.*

If Y = 1 instantiating for the Earth $S = \frac{P}{P-1}$

Hence Jupiter's Synodic period **S** = 11.863/10.863 =1 .09206^{y} = 398.88^{d} .
There are many indications that this formula was known to the Indic ancients.



CHAPTER II THE NAKṢATRA SYSTEM – THE VEDIC LUNAR MANSIONS

The origin of the Indian Nakṣatra system has been a subject of much speculation amongst Indologists in the west. Such has been the case since Sir William Jones discovered the treasures hidden in the vast literature of the ancient Indic in the Sanskrit language. The main ingredients used by the ancient Indic in developing an episteme for positional astronomy are the motions of the Sun and the Moon relative to the Nakṣatras. Ever since the occidental belatedly recognized the central role of Sanskrit amongst the IE family of languages, thanks to the insatiable curiosity of Sir William Jones, there has also been the recognition that the Nakṣatra system was a unique contribution of the Indians and it is the same Sir William who recognized immediately the significance of the Nakṣatra system not merely because of their Astronomic Utility but also because they provided a clue to the antiquity of the astronomical data that the Indic had amassed. As a result of the analysis carried out by Sir William and Colebrooke, they immediately came to the conclusion that this was of great antiquity. The historical details of the identification of these asterisms in terms of names used in the Occident is associated with such venerable names as William Jones, Colebrooke, Ebenezer Burgess, Hermann Jacobi, John Playfair, and Jean Sylvain Bailly. The original identification of the Nakṣatra's is of Vedic antiquity and they were fully enumerated by the beginning of the 4th millennium BCE. We shall discuss the historical aspects in the next and subsequent chapters.

"*I engage to support an opinion (which the learned and Industrious M. Montucla, seems to treat with extreme contempt) that the Indian Division of the Zodiac was not borrowed from the Greeks and or the Arabs, but having been known in the country (India) from time immemorial, and of being the same in part with that used by the nations of the old Hindu race, was probably invented by the first progenitors of that race before their dispersion"*[83]. There are 2 points Sir William makes here; 1. The Indian Nakṣatra system is of great antiquity (> 4000 BCE) and 2. Predates the presence of the putative Āryans, a mythology created by the Eurocentric Occidental.

That the system was devised before the old Hindu (later named Aryan by Max Müller) race dispersed from, its original homeland, or Urheimat. Note that while he is willing to grant the Indians the antiquity that they feel is rightfully theirs he remains equally adamant that such development needed the presence of Indo Europeans. In other words he was unable to visualize the Indics being intellectually capable of not only developing the extensive grammar for Sanskrit but also the extensive work needed to gather the astronomical data. It is sad that a considerable number of Indics did not find this argument lacking in clarity and did not expose it as a circular argument and participated in the deification of Sir William by heaping superlatives on this individual who single handedly caused the distortion of Indian History to a greater extent than any other colonial official. Table 2[84](from KV Subbarayappa "The tradition of Astronomy in India, page 79) shows the polar longitudes of the Nakṣatra. Why the Indic ancient used a non-orthogonal system (polar longitude and polar latitude as opposed to the ecliptic coordinate system) to describe the location of an object remains an unanswered question.

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[83] *Sir William Jones " On the Antiquity of the Indian Zodiack" Complete works, Volume I, p 333*
[84] *KV Subbarayappa "The tradition of Astronomy in India, page 79see appendix G for complete citation*

TABLE 1 TRADITIONAL HINDU NAMES[85]					
#	Name	Padas 1	Padas 2	Padas 3	Padas 4
1	Aśvini (अश्विनि)	चु Chu	चे Che	चो Cho	ला La
2	Bharaṇi (भरणी)	ली Li	लू Lu	ले Le	पो Lo
3	Krittikā (कत्तिका)	अ A	ई I	उ U	ए E
4	Rohiṇi (रोहिणी)	ओ O	वा Va/Ba	वी Vi/Bi	वु Vu/Bu
5	Mrigaśīrṣā (मृगशीर्षा)	वे Ve/Be	वो Vo/Bo	का Ka	की Ke
6	Ārdrā (आर्द्रा)	कु Ku	घ Gha	ङ Ng/Na	छ Chha
7	Punarvasu (पुनर्वसु)	के Ke	को Ko	हा Ha	ही Hi
8	Puṣya (पुष्य)	हु Hu	हे He	हो Ho	ड Da
9	Āśleṣā (आश्लेषा)	डी Di	डु Du	डे De	डो Do
10	Maghā (मघा)	मा Ma	मी Mi	मू Mu	मे Me
11	Pūrva or Pūrva Phalgunī (पूर्व	नो Mo	टा Ta	टी Ti	टू Tu
12	Uttara or Uttara Phalgunī (उत्तर	टे Te	टो To	पा Pa	पी Pi
13	Hasta (हस्त)	पू Pu	ष Sha	ण Na	ठ Tha
14	Chitrā (चित्रा)	पे Pe	पो Po	रा Ra	री Ri
15	Svātī (स्वाति)	रू Ru	रे Re	रो Ro	ता Ta
16	Viśākhā (विशाखा)	ती Ti	तू Tu	ते Te	तो To
17	Anurādhā (अनुराधा)	ना Na	नी Ni	नू Nu	ने Ne
18	Jyeṣtha (ज्येष्ठा)	नो No	या Ya	यी Yi	यू Yu
19	Mūla (मूल)	ये Ye	यो Yo	भा Bha	भी Bhi
20	Pūrva Āṣādha (पूर्वाषाढा)	भू Bhu	धा Dha	फा	ढा Dha
21	Uttara Āsādhā (उत्तराषाढा)	भे Bhe	भो Bho	जा Ja	जी Ji
22	Srāvana (श्रवण)	खी Ju/Khi	खू Je/Khu	खे	खो
23	Shravisthā (श्रविष्ठा) or Dhanistā	गा Ga	गी Gi	गु Gu	गे Ge
24	Satabhisaj (शतभिषा)or	गो Go	सा Sa	सी Si	सू Su
25	Pūrva Bhādrapadā (पूर्वभाद्रपदा)	से Se	सो So	दा Da	दी Di
26	Uttara Bhādrapadā (उत्तरभाद्रपदा)	दू Du	थ Tha	झ Jha	ञ Da/Tra
27	Revatī (रेवती)	दे De	दो Do	च Cha	ची Chi

LEGEND FOR TABLE 2

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[85] *Under the ancient traditional Hindu principle of naming individuals according to their birth star. For example for Aśvini, the following Sanskrit syllables correspond with this Nakşatra, and would belong at the beginning of a first name: Chu (* चु*) ,Che (* चे*), Cho (* चो*), La (* ला*)*

1. Sūrya Siddhānta
2. Brahmagupta, Bhāskara II
3. Lalla
4. Āryabhaṭa

TABLE 2 NAKṢATRA - A UNIQUELY INDIC CONTRIBUTION TO ANCIENT CALENDRIC ASTRONOMY: COMPARISON OF POLAR LONGITUDE DATA FROM VARIOUS SOURCES

#	Name	1	2	3	4	Asterism
1	Aśvini (अश्विनि)	8 00	8	8	12	α-Arietis , Hamal
2	Bharanī (भरणी)	20 0	20	20	24 23	41-Arieti, Musca
3	Krittikā (कृत्तिका)	37 30	37 28	36	38 33	η-Tauri, Alcyone
4	Rohiṇī (रोहिणी)	49 30	49 28	49	47 33	α-Tauri ,Aldebaran
5	Mrigaśīrṣā (मृगशीर्षा)	63 00	67	70	61 03	β-Tauri, El Nath
6	Ārdrā (आर्द्रा)	67 20	93	92	68 23	α-Orionis, Betelgeuse
7	Punarvasu (पुनर्वसु)	93 00	106	105	92 53	β-Geminorium , Pollux
8	Puṣya (पुष्य)	106 0	108	114	106	δ-Cancri,Asellus Australis
9	Āśleṣā (आश्लेषा)	109 0	129	128	111	ζ Hydrae
10	Maghā (मघा)	129 0	147	139 20	126	α-Leonis
11	Pūrva or Pūrva Phalgunī (पूर्व…	144 0	155	154	140 23	δ-Leonis
12	Uttara Phalgunī(उत्तर…	155 0	170	173	150 23	β-Leonis
13	Hasta (हस्त)	170	183	184 20	174 3	δ-Corvi, γ Virginis
14	Chitrā (चित्रा)	180 0	199	197	182 53	α Virginis, Spica
15	Svātī (स्वाति)	199 0	212 5	212	194	π Hydrae, Arcturus
16	Viśākhā (विशाखा)	213 0	224 5	222	211 33	β Libræ, Zubeneschamali
17	Anurādhā (अनुराधा)	224 0	229 5	228	224 53	δ-Scorpii,Dschubb
18	Jyeṣṭha (ज्येष्ठा)	229 0	241	241	230 3	α Scorpii, Antares
19	Mūla (मूल)	241 0	254	254	242 44	λ Scorpii, Shaula
20	Pūrva Āṣādha (पूर्वाषाढ़ा)	254 0	260	267 20	252 33	δ Sagittarii
21	Uttara Āṣādhā	260 0	265	267	260	τ Sagittarii

	(उत्तराषाढ़ा)				23	
22	Śravana (श्रवण)	266 40	278	283 10	263	β Capricornus, Dabih
23	Shravisthā (श्रविष्ठा) or Dhanistā	280 0	290	296 20	296 33	δCapricornus, Deneb Algeidi
24	Shatabhishā (शतभिषा)	290 0	320	313 20	319 53	λ Aquarii, Hydor
25	Pūrva Bhādrapadā (पूर्व….	320 0	326	327	334 53	α Pegasi
26	Uttarabhādrapadā उत्तर…	335 20	337	335 20	347	α Andromedae
27	Revatī (रेवती)	359	0	359	0	η Piscium

TABLE 3 THE CONCORDANCE OF THE NAKṢATRA WITH ARABIC MANZIL

Serial number	Hindu Nakṣatra	Arabian Manzil	Principal Hindu Star(s)
1.	Aśvini, अश्विनी	Al-Hamal	α Arietis ,β Arietis
2.	Bharaṇī भरणी	Al-Botein	δ Arietis, Musca
3.	Krittika, कृत्तिका	Al-Thuraiya	η-Tauri , Alcyone
4.	Rohiṇī, रोहिणी	Al-Debaran,	α Tauri , Aldebaran
5.	Mrigaśīrṣā, मृगशीर्षा	Al-Nath	β Tauri, El Nath
6.	Ardra, आद्रा	Al-Henah	α Orionis, Betelgeuse
7.	Punarvasu, पुनर्वसु	Al-Dira or Al-Ras al-Tau'am al-Mu'akhar	Pollux
8.	Puṣya, पुष्य	Al-Nethra	δCancri , Asellus Australis
9.	Āśleṣā, आश्ळेषा / आश्लेषा	Al-Terphaε Hydra	E Hydrae, or α Cancri , Acubens
10.	Maghā, मघा	Al-Giebha	Regulus
11.	Pūrva-Phālguni, पूर्व फाल्गुनी	Al-Zubra	δ Leonis
12.	Uttara-Phālguni, उत्तर फाल्गुनी	Al-Serpha	β Leonis
13.	Hasta, हस्त	Al-Auwa, γ Corvi	δ Corvi
14.	Chitra, चित्रा	Sinak-Al-Azal	A Virginis, Spica
15.	Svātī, स्वाती	Al-Gaphr	Arcturus
16.	Viśākhā, विशाखा	Al-Zubana, al Sāmalliyyah	β Libræ, Zubeneschamali
17.	Anurādha, अनुराधा	Au-iclil	δ Scorpionis
18.	Jyeṣtha , ज्येष्ठा	Al-Kalb	Antares
19.	Mūla, मूळ	Al-Shaula	λ Scorpionis

20.	Pūrva- Āṣāḍhā , पूर्वाषाढा	Al-NaaimAs	δ Sagittarii
21.	Uttara-Āṣāḍhā,उत्तराषाढा	Al-Belda	τ Sagittarii
22.	Abhijit, अभिजीत	Al-Dabih	Vega
23.	Śrāvaṇa, श्रवण	Sad-Al-Bula	α Aquilæ
24.	Dhanishtha, श्रविष्ठा or धनिष्ठा	Al-Sundα	Delphini
25.	Pūrva-Bhādrapadā,पूर्वभाद्रपदा/ पूर्वप्रोष्ठपदा	Al-Phergh-Al-Mukaddem	α Pegasi
26.	Uttara-Bhādrapadā,उत्तरभाद्रपदा/	Al-Phergh-Al-Nuachery Pegasi	α Andromedæ
27.	Revati,रेवती	Al-Risha	η Piscium

The Moon as it orbits the earth could be seen against any of the constellations of this band. It is in fact a sidereal Zodiac unlike the Solar Zodiac. The etymology of the Sanskrit word Nakṣatra नक्षत्र, Nakṣatra, 'star', originates from *nakṣa*, 'approach', and *tra*, 'guard'. The essential elements of the Hindu calendar are Vedic[86] in origin.

THE NAKŞATRA SYSTEM

The Nakṣatra system or Lunar mansions is a band of the heavens approximately 10° wide, centered on the ecliptic, against which the Moon is seen to move, as seen from the earth. The Moon's path around the earth is tilted at an angle of approximately 5° to the ecliptic. Hence the Moon as it orbits the earth could be seen against any of the constellations of this band. It is in fact a sidereal Zodiac unlike the Solar Zodiac. The etymology of the Sanskrit word Nakṣatra नक्षत्र, Nakṣatra, 'star', originates from *nakṣa*, 'approach', and *tra*, 'guard'. The essential elements of the Hindu calendar are Vedic[87] in origin.

The Nakṣatra designation has been used to connote
A star in general.
27 equal divisions of the Zodiac,
an asterism[88]
A specific junction star (Yogatārā) in each of the 27 sectors of the Lunar Zodiac.

The Nakṣatras are a twenty-seven or twenty-eight division of the Zodiac based upon the Moon, which takes 27-28 days to go around the Zodiac (to be more accurate 27.3 days). The Nakṣatras are listed in their entirety in late Vedic texts like the Atharva Veda (xix.7) and Yajur Veda (Taittiriyā Saṃhitā iv.4.10). They are presented in great detail in the Taittiriyā Brāhmaṇa (TAITB) (iii.1), which uses special verses to the deities governing each Nakṣatra. They are also a topic of the Śatapatha Brāhmaṇa (ii.1.2) and the Atharva Veda (AV) Parisisthani. The Nakṣatra and their deities are mentioned in the Ṛg Veda (RV). *Bharateeya Jyotiṣa Ṣāstra* states that each Nakṣatra name corresponds to a group of stars called star mansions or Asterisms. The concept is that *Chandra* or the Moon visits these mansions in his trajectory

86 Abhyankar, K D Pre-Siddhāntic Indian Astronomy,

91 Abhyankar, K D Pre-Siddhāntic Indian Astronomy,

88 We cannot use the term constellation, since that is used exclusively to designate the 88 (Greek based) constellations as approved by the IAU

around earth. It is very possible that at the inception of a daily star concept during the early *Vedic* period, a Nakṣatra may have been a specific single star. Nakṣatra positions may have been rationalized in later days to mansions or groups of stars for purposes of mathematical averaging to be exactly 13.333^o apart required in Jyotiṣa. We will use the word Yogatārā for the use of the word Nakṣatra in singular meaning Junction star to minimize the ambiguity in the use the word Nakṣatra.

The Nakṣatra system is a unique feature of the Ancient Indic Astronomy. It must have been realized by the ancient Indics that the sidereal period of the lunar orbit is a number very close to $27\frac{1}{3}$. Its very uniqueness compels the vast majority of the Indologists to belittle the significance of the system. Along with a small band of intrepid believers, in the truth such as Playfair, Bailly, Colebrooke, and even Sir William Jones in his initial endeavors after reaching Calcutta, there was an indologist by the name of Ebenezer Burgess, who translated the Sūrya Siddhānta in 1860 and published it in the Journal of the American Oriental Society. He states that he cannot concur with Prof Whitney in his opinion that the Hindus borrowed everything from the Greeks and that the Hindus are in fact, not indebted to the Greeks to any great extent.

ṚG	VJ
Arjuni	Phālguni
Agha	Magha
Tisya	Puṣya
Mriga	Mrigaśīrṣā,
Ahirbudhnya	Bhādrapadā

He concludes that the antiquity of the lunar division of the Zodiac into 27 or 28 Nakṣatras is very high and undoubtedly of Indian origin, even after he read contrary reports by Biot[89] , who was emphatic that it was of Chinese origin.

He feels likewise that the solar division into 12 equal parts is also of great antiquity in India and doubts that it came from anywhere else; subsequently Kak, and Frawley reported these. In any event, the antiquity of the Indic references to the Solar Zodiac in the Saṃhitā period precludes the borrowing from Greece. There are however differences in the naming of the Nakṣatras, for example:

The lunar Zodiac is tenanted by 27 asterisms each of them spread over an arc of 13 degrees 20 minutes. The Zodiac counted from the first degree of β Arietis (Aṡvini) to the 360th degree of eta Piscium or Revati is known as the sidereal Zodiac or Nakṣatra Dina because the Moon spends approximately one day in each Nakṣatra. The complete list of 27 Nakṣatra occurs in the Taittiriyā Saṃhitā (TAITS), Taittiriyā Brāhmaṇa, Atharva Veda, Kathaka Saṃhitā, and Maitreyani Upanishad. The following is based on an original account by Dr. Dwarakanath a physicist. The Nakṣatra's (a subset of them namely Agha or Magha, Mrigaśīrṣā (the head of the antelope), Punarvasu, are first mentioned in the RV and by the time of the Vedāṅga Jyotiṣa, which is post vedic, all of the Nakṣatras have been defined unambiguously. The differences in the names are mentioned in the Rg and later texts.

FIGURE 1 THE CONSTELLATIONS OF THE ORIENTAL ZODIAC



COMPARISON OF DIFFERENT NAMES BETWEEN RV AND V

[89] *The discussion between Biot, Whitney, Max Mueller, and E. Burgess on the origin of the Nakṣatra system illustrates 2 key points 1. the obsession that the occidental had with according priority to their civilization for every invention known to the human species 2.they seem oblivious to the fact that they are discussing a subject of which they have only incomplete knowledge. The relevant references are listed in the bibliography*

The complete list of Nakṣatras is mentioned in the Ṛg, but only by the name of the presiding deity[90]. It appears that Nakṣatras were first named after deities during the Vedic period, and then subsequently they were assigned names, that would help mnemonically in remembering their function in the sky. This is the reason why we mention the names of the deities also.

As we have seen in Chapter I, the actual period of the Moon's orbit as measured in a fixed frame of reference is known as a *sidereal* month, because it is the time it takes the Moon to return to the same position on the celestial sphere among the fixed stars (Latin: *sidus*): **27.321661^{d}** (**27^{d} 7^{h} 43^{m} 11.5^{s}**) or about 27 ⅓^{d}. This type of month has appeared among cultures in West Asia, India, and China. While, it is not entirely clear whether the motivation of the Chinese and later the Babylonians was centered on the utility of such stars in tracking the motion of the Sun and the Moon, the ancient Indic made it abundantly clear that his attention was primarily focused on the constellations near the path of the ecliptic, although he did not hesitate to use stars that were as far away as 60^{0} from the equator, when there was no alternative. In concentrating his attention on those stars that were useful to him, he was exhibiting a characteristic that was in consonance with his philosophy, where a relentless pragmatism reigned supreme. This is ironic because most Indologists who are not of Indic heritage have categorized the Indic, with scant justification as being other worldly and hopelessly impractical, in effect relegating the Indic to an 'also ran' category. This is such a widespread impression that many Indians even today believe that this is the case and short change themselves as a result.

The Indian calendar has been modified and elaborated over the millennia, but because it is based on the stars (Nakṣatras) visible to the naked eye, and on the visible lunar phases, it is more accurate than any others of the past. In short, it was truly an astronomical calendar. The actual moments when Lunar months begin, can easily be checked by the regular appearances of Solar eclipses, and the middle moment of a Lunar month -- Pūrṇima or full Moon -- can similarly be verified by the more frequent Lunar eclipses. Hence the Hindu calendar, not requiring special instruments for its rectification, has maintained great accuracy for thousands of years. This is in stark contrast to the Julian calendar, which was in error by 11 days when it was ultimately corrected in 1582 CE.

Hindu astronomers also used the 12-sign Zodiac. Using the 12-sign Zodiac and the 28-sign (and later 27-sign by the time of the Vedāṅga Jyotiṣa) Nakṣatra division helped them to track celestial bodies under the time scales of both the Sun and the Moon. A Nakṣatra is further divided into four equal *Padas,* each being 3°20'. (Pada in Sanskrit means "legs," as in the four legs of a quadruped animal, or "a quarter" or "quadrant.") The number of Padas in the ecliptic with twenty-seven Nakṣatras amounts to four times twenty-seven, or 108 Padas. The number 108 appears often in Hindu and Buddhist philosophy. The significance of this number might have influenced dropping one of the original Nakṣatras, or the change could simply have been because the sidereal lunar month is closer to 27 days than to 28 days. So each Rāśi contains 9 Nakṣatra Padas or 2 ¼ Nakṣatras. The change could also have been made because the "draconic month," during which the Moon's nodes (the "dragons") revolve, is also closer to 27 days



FIGURE 2 DEPICTION OF 12 SIGN RAŞI OR SOLAR ZODIAC

[90] *RV 5.51*

(about 27.21 days). The Rāśi and the Nakṣatra coincide at 3 locations on the ecliptic since the GCF; greatest common factor of 27 and 12 is 3. Again we must recall that the Rāśi or Solar Zodiac is rotating around the ecliptic with a period of approximately 26000 years since the first point of Aries is fixed by definition to the Vernal Equinox. They are an integral part of all Vedic symbolism and the basis for the timing of all Vedic rituals down to the present day. Both the TAITB and the AV mention 28 Nakṣatras, but in the VJ there appear only 27. It is not totally clear to me at this point in time whether the ancients went from a 27 to a 28 configuration and then reverted back to a 27 configuration or whether they went directly to a 28 star configuration ending with 27 Nakṣatras.

NAKṢATRA AND THE CALENDAR

It was the impression of knowledgeable Indologists such as William Brennand that the Hindus have been observing and recording the motion of the Moon , the Sun and the seven planets along a definite path that circles our sky, now known as the ecliptic, and is marked by a fixed group of stars clustered around this ecliptic. The Moon afforded the simplest example. These early astronomers observed that the Moon, moving among these fixed star constellations, more accurately referred to today as asterisms (as opposed to the use of the term constellation, which is a term with a specific meaning assigned by the IAU; in this case the total number is fixed as 88) which they called Nakṣatras, returned to the same Nakṣatra in 27.32166^d, the exact quantity determined by *Āryabhaṭa* , thus completing one Nakṣatra month or sidereal month. They found it convenient to divide these groups of stars into 27 almost equal sections, or the 27 Nakṣatras. Thus mathematically a Nakṣatra is equal to $1/27^{th}$ of the sidereal Zodiac. In other words, it occupies 13 degrees and 20 minutes along the ecliptic. By this method of reckoning, instead of giving the date of a month, as western calendars do, the Hindus gave the name of the Nakṣatra in which the Moon was to be seen. (The Moon is in each of these Nakṣatras for approximately one day plus eighteen minutes).in each of these Nakṣatras is designated Yogatārā, a designated star that acts as a 'Manzil' or house for the travelers passing through. A celestial object is considered to be 'in' a Nakṣatra if its longitude along the ecliptic is the same as the Nakṣatra or Yogatārā.
This scheme fitted nicely with the Sun's cycle, for the Hindus noted that the Sun traversed the same circle through the sky, but that it returned to its starting place only after $\mathbf{365.258756481^d}$ or what we call a solar sidereal year. (Modern value is $\mathbf{365.25636305^d}$) Now, having already divided the month into the 27 Nakṣatras for the convenience of reckoning the Moon's voyage through the heavens, what was more natural than that these same Nakṣatra or Manzil as the Arabs called them should serve for the study of the Sun's course? Being in a circle of 360^o , each Nakṣatra takes up 13^o 1/3 of that circle. The Sun, moving about 1 degree in a day, is seen for 13 1/3 days in each Nakṣatra. The system of reckoning according to the Lunar Nakṣatras is current today in other cultures, that of the Solar being uncommon.

During the course of one day, the earth has moved a short distance along its orbit around the Sun, and so must rotate a small extra angular distance before the Sun reaches its highest point. The stars, however, are so far away, as we discussed in chapter I ,that the earth's movement along its orbit makes a generally negligible difference to their apparent direction (see, however parallax), and so they return to their highest point in slightly less than 24^h. A mean sidereal day is about $23^h\ 56^m$ in length. Due to variations in the rotation rate of the earth, however, the rate of an ideal sidereal clock deviates from any simple multiple of a civil clock. The actual period of the Moon 's orbit as measured in a fixed frame of reference is known as a sidereal month, because it is the time it takes the Moon to return to the same position on the celestial sphere among the fixed stars (Latin: sidus) is $\mathbf{27.321\ 661^d}$ ($\mathbf{27^d\ 7^h\ 43^m\ 11.5}^s$) or about 27 ⅓ days.

In brief, then, the earliest method, namely the Vedic, of counting days, was to name the Moon through the various Nakṣatras -- the circle or cycle repeating itself each sidereal-star-month. Later the Sun's

place in the same Nakṣatras was noted, the year ending when the Sun returned to the same Nakṣatra. The observation of the Solar and Lunar eclipses was next, and the observance of the new and Full Moons divided the month into the two phases of a waxing and waning Moon, the month beginning at the moment of new Moon. This is how the Hindu reckons today, the month taking its name from the Nakṣatra in which the full Moon is seen each month. The full Moon being exactly opposite the Sun, the Solar Nakṣatra bears the same name as the Lunar month six months ahead, while each Lunar month bears the same name as the 14th Solar Nakṣatra ahead.

The western student faced with these unfamiliar calculations may echo the old Persian proverb, "why count big numbers and small fractions, when they are all amassed in 1?" but the ancient Indic looks on these figures from another point of view -- he lives with them, and among them, and by them, much of the time and there is no question he used the artifice of large numbers to ensure the quantities were commensurate.

NAKṢATRA AND THE PRECESSION OF THE EQUINOXES

To summarize, the earth revolves around the Sun once in **$365^d\ 5^h\ 48^m\ 46^s$.** From a geocentric view, the Sun appears to complete one round of the ecliptic during this period. This is the tropical year (see Chapter I, discussion of the definitions of the year). In the span of a tropical year, the earth regains its original angular position with the Sun. It is also called the year of seasons since the occurrence, and timing, of seasons depends on the rotation of the earth around the Sun. If, for example, we consider the revolution of the Sun around the earth from one vernal equinox (around 21st March, when the day and night all over the globe are equal) to the next vernal equinox, it takes one tropical year to do so.
However, if at the end of a tropical year from one vernal equinox to the next, we consider the position of the earth with reference to a fixed star of the Zodiac, the earth appears to lie some 50.29 arc-seconds of celestial longitude to the west of its original position. In order for the earth to attain the same position with respect to a fixed star after one revolution, it takes a time span of **$365^d\ 6^h\ 9^m\ 9.8^s$**. This duration of time is called a sidereal year. The sidereal year is just over 20 minutes longer than the tropical year; this time difference is equivalent to 50.29 arc-seconds of celestial longitude.
Each year, the vernal equinox will fall short by 50.290966 arc-seconds (0.0139697^o) along the Zodiac reckoned along the fixed stars or 1 degree in 71.6 years. This continuous receding of the vernal equinox along the Zodiac is termed the precession of the equinoxes and it takes about 25800 (**360/.0139702 = 25770.0359146014**) years to make one complete revolution of the precessional motion of the earth's axis.
The ancient Indic was familiar with the phenomenon of precession, and its effects, although he had no explanation for it. He labored under the misconception that it was caused by a deity that was placed there for his benefit, in the form of a Murti. In the Sūrya Siddhānta, the rate of precession is set at 54" (as opposed to 50.2983"), which is much more accurate than the number calculated by the Greeks.
Hipparchus regarded as the discoverer of the precession of the equinoxes in the west gave us either 28,000 or 28,173 years for one revolution.. Another figure given is 25,920 years for the precession cycle. For convenience and a quick estimate by hand calculations, we choose a number that is a multiple of 108 (25,812). This permits us to restrict ourselves to integer numbers for the entire matrix of 27*4 numbers that comprises the table of equinoxes and solstices for all the 27 Nakṣatras. These figures indicate that the mean value of 27,000 years given in the Vedic scriptures is reasonable. The values of the dates for a given event such as the Vernal equinox as shown in Table 4 degrees on either side of the ecliptic is a belt of the heavens known as the Zodiac. (Dante called it the oblique line that beareth all planets).
The first 30 degrees of the Zodiac constitute the sign of Aries, the next 30 degrees Taurus and so on. The Zodiac counted from the first degree of Aries to the 360th degree of Pisces is called the tropical Zodiac.

These 12 signs are the limbs of the cosmic man or time eternal (kala-Puruṣa - the almighty self as time). Aries is his head, Taurus his face, Gemini his neck, Cancer his heart, Leo the place beneath, his belly, Libra his generative organs, Scorpio the place beneath, Sagittarius his upper thigh, Capricorn his lower thigh, Aquarius his leg and Pisces his feet! Each Nakṣatra is associated with a deity, and that the deities associated with the Nakṣatra are mentioned in the RV Saṃhitā. The antiquity of the Nakṣatra system becomes clear when it is recognized that all the deity names occur in RV 5.51. This insight is due to Narahari Achar[91]. This hymn by Svastyātreya lists the deity names as: Aśvin, Bhaga, Āditi, Pusan, Vayu, Soma, Bṛhaspati, Sarvaganah, Visve-devah, Agni, Rudra, Mitra, Varuna, and Indra. The Sarvaganah are the ganah (groups) such as the Vasavah, Pitarah, Sarpah, including Ahirbudnhya and Ajaekpad), Āpah, and the Ādityaganah, Daksha Prajapati, Āryaman, Visnu, Yama, Indra complete the list. There is no doubt that the ecliptic is meant because the last verse of the hymn refers explicitly to the fidelity with which the Sun and the Moon move on their path, the ecliptic. The division of the circle into 360 parts or 720 parts was also viewed from the point of view the Nakṣatras by assigning 27 upa-Nakṣatras to each Nakṣatra (Śatapatha Brāhmaṇa. 10.5.4.5). This constituted an excellent approximation because 27 × 27 = 729. In other words, imagining each Nakṣatra to be further divided into 27 equal parts made it possible to conceptualize half a degree when examining the sky.

TABLE 4 THE INDIAN NAKṢATRA SUGGESTED CONCORDANCE WITH THE CONSTELLATION STARS

Nr.	Western Zodiac name	Sidereal Sanskrit	Deity	Sector in d,m, Σn ,Σn+1	Sidereal (celestial) longitude d,m,s, λn epoch of 285 CE	Position of Yogatārā d,m,s, Δλn	Meaning
1.	α Arietis, Hamal	Aśvina (Asvayjau)	Aśvinau	00 0 13 20	13 49	+0 29	A Horse's head
2.	41 Arietis, Musca	Apabharaṇi	Yama	13 20 26 40	24 22	9 02	Yoni or Bhaga
3.	η Tauri	Krittika	Agni	26 40 40 00	36 08	9 28	Razor
4.	α Tauri, Aldebaran	Rohiṇi	Prajapati	40 00 53 20	45 54	5 54	A wheel carriage
5.	112 , β Tauri, ElNath	Mrigaśīrṣā	Soma	53 20 66 40	58 43	5 23	The head of an antelope
6.	α Orionis, Betelgeuse(Bayt	Ardra	Rudra	66 40 80 00	64 53	-1 87	A gem
7.	β Geminorium, Pollux	Punarvasu	Aditi	80 00 93 20	89 20	9 20	A house
8.	δ Cancri, Assellus Australis	Puṣya	Brhaspati	93 20 106 40	104 51	11 31	An arrow
9.	ε Hydrae, 16 HYA, α Cancri,	Āśleṣā	Sarpāh	106 40 120 00	110 44	4 04	A wheel
10.	α Leonis	Magha	Pitarah	120 00 133 20	125 58	5 58	Another house
11.	δ Leonis	Pūrva Phālguni	Āryaman (Bhaga)	133 20 146 40	137 23	4 03	A bedstead
12.	β Leonis	Uttara Phālguni	Bhaga (Āryaman)	146 40 160 00	147 42	1 02	Another bed stead

[91] *Narahari Achar. B.N, see Appendix G on Primary and Other sources*

13.	γ Virginis, Pūrnima	Hasta	Savitar	160 00 173 20	166 16	6 16	A hand
14.	α Virginis(spica)	Chitra	Indra (Tvastr)	173 20 186 40	179 59	6 39	A pearl
15.	π Hydrae	Svātī	Vayu	186 40 200 00	194 48	8 48	A piece of Coral
16.	β Librae, Zubeneschamali	Viśākhā	Indragni	200 00 213 20	205 29	5 29	A festoon of leaves
17.	δ Scorpii,Dschubb	Anurādha	Mitra	213 20 226 40	218 42	5 22	An oblation to the Gods
18.	α Scorpii, Antares	Jyeṣṭha	Indra (Varuna)	226 40 240 00	225 54	-0 46	A rich ear ring
19.	λ Scorpii, Shaula	Mūla	Pitarah	240 00 253 20	240 43	0 43	The tail of a fierce lion
20.	δ Sagittarii. Kaus Media	Pūrva-Āṣāḍhā	Āpah	253 20 266 40	250 43	-2 37	A couch
21.	τ Sagittarii . 40	Uttara-Āṣāḍhā	Visvedevah	266 40 280 00	260 58	-5 42	The tooth of elephant,
22.	β Capricornus, Dabih	Śrāvaṇa	Visnu	280 00 293 20	280 11	0 11	The three footed step of Víṣṇu
23.	δ capricornus, Deneb Algeidi	Dhanishta (Sravistha)	Vasavah	293 20 306 40	299 40	6 24	A tabor
24.	λ Aquar,Hydor	Satabhishaj	Varuna	306 40 320 00	317 42	11 02	A circular jewel
25.	α Pegasi,Markab	Pūrva-Bhādrapadā(prosthapada)	Aja Ekapad	320 00 333 20	329 42	9 42	A two faced image
26.	γ Pegasi, Algeneib	Uttara-Bhādrapadā	Ahirbudnhya	333 20 346 40	345 20 24.7	12	Another couch
27.	η Piscium, Kullat Nunu	Revati	Pusan	346 40 360 00	02 58	+2 58	A small sort of tabor

There are 6 Yogatārā that are outside the lune (the 13^{o} 20’ segment of the Ecliptic) of a particular Nakṣatra. Even though the Nirāyana Longitude does not change appreciably. It changes due to the proper motion of the stars observable even at such a great distance. The epoch that was used to generate the longitudes, can be deciphered from the fact that the Ayanāmśa[92] in 2007 was 23^{o} 59’, Dividing this number by the rate of precession gives, the number of years elapsed since the epoch, 23.95/.0139702 = 1714 which in turn gives the epoch as 291 CE which is very close to 285 CE which was used by the Indian Calendar Committee in 1955.

AMBIGUITIES IN IDENTIFICATION OF NAKṢATRAS

Most of the Yogatārā can be identified without ambiguity, but there are a few that have posed problems of identification. This need not be fatal to the use of the Nakṣatras as a means of dating past events. It simply increases the range of possible dates of a particular event and one must use other methods to

[92] *The Indian Astronomical Ephemeris, 2007*

TABLE 6 THE ECLIPTIC (NIRĀYANA) LONGITUDES AND LATITUDES OF THE NAKṢATRA' S EPOCH 285 CE

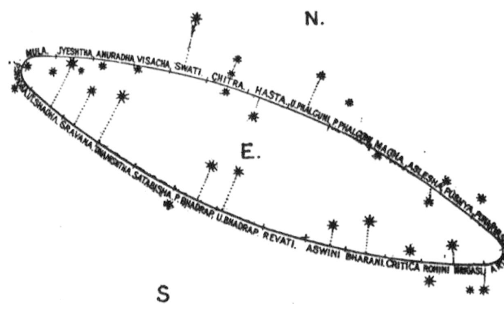
tune in to the right date and narrow the range of possibilities. Furthermore we can tolerate a higher range if we go back to a more ancient era.

TABLE 5 NAKṢATRA' S WITH AMBIGUOUS IDENTIFICATION

Nakṣatra	sector	Traditional identification	Alternative identification	Remarks	Longitude difference
Ardra	66.2 80	α Orionis, Betelgeuse	γ Gem		10°
Mrigaśīrṣā	53.3-66.7	λ Orionis	β Tauri		1° (insignificant)
Hasta	160-173.3	γ corvi	γ Virginis , Porrima		30' (insignificant)
Svātī	186.7-200	α Bootis	π Hydrae		14° 47'
Shravana	280-293.3	α Aql	β Del, β Capricornus		12°
Dhanishta (Sravistha)	293.3-306.7	β Del	δ Capricornus or β aqua	The ambiguity causes a 500 year difference for the VJ era	7° (tolerable)
Satabhisaj	306.7-320	λ Aqua, Hydor	αPsA (Formalhout)		8°
Revati	346.7-360	ζ Pisces	α Andromeda, η Pisces	02 57 58	9° 25, 350 32 42,

Nr	Nakşatra	number stars	Ecliptic longitude, EPOCH 285 CE d, m, s	Ecliptic Latitude d, m, s
1	Aśvini, α Arietis	2	13,49, 30	9, 49, 25.2
2	Apabharaṇi, Musca, 41 Arietis	3	24,21,44.1	10,16,41.9
3	Krittika, Alcyone	6	36,7, 53.9	3, 51, 10.7
4	Rohiṇi, Aldebaran	1	45,54, 48.9	-5,40, 51.9
5	Mrigaśīrṣā, β Tauri, ElNath	3	58,42,32.2	5,9,36.5
6	Ardra, Betelgeuse, α Orionis	1	64 , 53, 9.5	-16,15,12.3
7	Punarvasu, β Geminorium, Pollux	2	89,20,11.8	6,28,39.4
8	Pusya, δ Cancri, Assellus Australis	1	104, 51, 13.3	0,-5,49.4
9	Āśleṣā, ε Hydrae, or α Cancri, Acubens	6	109,47,15.6	-5, 14, 29.8
10	Magha, α Leonis, Regulus	6	125,57,33.8	0,21, 15.8
11	Pūrva-Phālguni, δ Leonis, Zosma	2	137, 23, 35.8	14, 15, 52.6
12	Uttara-Phālguni, β Leonis, Dénébula	2	147,42, 1.6	12, 14,15.4
13	Hasta, γ Virginis, Porrima	5	166, 15, 44	2, 50,2.2
v	Chitra, α Virginis, Spica	1	179,58, 48.8	-1, 57, 33
15	Svāti, π Hydrae, 49, Hydrae	1	194, 47, 38.6	-12, 54, 18.4
16	Viśākhā, β Librae, Zubeneschamali	2	205, 28, 47.4	8, 40, 13
17	Anurādha, δ Scorpii,	4	218, 42,16.2	-1, 46, 59.9
18	Jyeṣṭha, α Scorpii, Antares	1	225, 53, 53.1	-4, 21, 22,2
19	Mūla, λ Scorpii, Shaula	7	240, 43, 11.7	-13, 33, 45.6
20	Pūrva Āṣāďhā, δ Sagittarii, Kaus Meridionalis	7	250, 42, 30.2	-6, 154, 48.6
21	Uttara Āṣāďhā, τ Sagittarii	1	260, 57, 31.8	-4, 52, 15.5
22	Śrāvaṇa, β capricornus	3	280, 11, 16.8	4, 46, 26.7
23	Dhanishta, Sravishta, δ Capricornus, Deneb algeidi	5	299, 39, 51.6	-2, 28, 12.8
24	Satabhisaj, λ Aquarii,	1	317, 42, 17.1	0, -19, 7.5
25	Pūrva Bhādrapadā, Markab,α Pegasi	4	329, 41, 42	19, 25, 39.7
26	Uttara Bhādrapadā, γ Pegasi, Algeneib		345, 20, 24.7	12,33,35.9
27	Revati, η Piscium		2,58,8.5	5, 16, 19.3

FIGURE 3 THE DISTRIBUTION OF NAKṢATRA'S AS DEPICTED BY BRENNAN



The table shows the Nirāyana Longitudes and Latitudes of [Grab your reader's attention with a great quote from the document or use this space to emphasize a key point. To place this text box anywhere on the page, just drag it.]

The 27 Yogatārā (epoch of 285 CE) used by the Indian Calendar committee as the base year for Ayanāmṡa calculations. The 27 divisions of the Ecliptic became fixed in position as the stars themselves, like a great bed dial, with the numbers ranging not along the Equator, but along the Ecliptic itself. The accompanying diagram (Fig. 3) may, perhaps, more explicitly convey the nature of the Hindu Ecliptic, which is shown as a great circle in perspective.

From Brennand "Each division represents one twenty seventh part of the ecliptic and each star the Yogatārā of the Nakṣatra or Lunar asterism to which it belongs. It will be observed that the Yogatara might be either in the northern or southern hemisphere and the stars selected were those most suitable for observation , either on the Ecliptic or near it, North or South , but always such as were capable of being occultated by the Moon or with the planets .To render this important part of Indian Astronomy still more easily understood the two accompanying Plate., V. and VI., are intended as a graphic representation of the Hindu Ecliptic, and of the Lunar Asterism together with the Solar signs of the Hindu Zodiac, the position of each being fixed by a supposed projection of the Yogatara on the plane of the ecliptic, the Northern stars with their modern names , on one side of the plane , and the Southern stars on the other, the divisions , retaining the same names in each Hemisphere**.**

DESCRIPTION OF THE NAKṢATRA

The most comprehensive discussion in English is by Ebenezer Burgess[93], while there is a modern discussion by BalaKrishna. There are also relevant discussions by Subhash Kak on the topic[94] and others such as William Brennand[95] and by the collection of essays edited by Sen and Ṡukla[96]. The significance of the Deity from a forensic standpoint is that the Deities are mentioned in the RV as pointed out by Narahari Achar. The true import of statements in the RV is quite often metaphorical with some astronomical significance. With the lapse of time these metaphorical meanings are no longer recognized by the vast majority of the people. However, that does not diminish their value for purposes of forensic investigation. The Nirāyana Longitude numbers given by Burgess, are consistently higher by about 4^o since he uses 570 CE as the epoch (~285 + 4*71), since each degree of precession takes approximately 71 years). This is consistent with the vocal opposition of the Occident to choose a higher chronology for India even when the higher chronology is warranted by other inferences. The following synopsis of the 27 Nakṣatras, including the Yogatārā, It is by no means an exhaustive treatment, but is provided here as

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[93] *Ebenezer Burgess, ,The Sūrya Siddhānta, a text book in Hindu Astronomy, Edited by Phanindra Lal Ganguly, Motilal Banarsidass, First edition 1860, reprinted 1989*

[94] *See for instance KAK 2000 in the Bibliography*

[95] *ibid*

[96] *See SENSHUK in Bibliography. However the chronology in Sen and Shukla , predates the discovery of the Sarasvati pale channel, which allows us to revisit the whole issue of chronology in a rational manner*

a convenient reference. We recommend that the readers use a book such as the one by Richard Allen[97] . The longitudes correspond to a epoch of 285 CE, as chosen by Lahiri.

1. **AŚVINI, α ARIETIS, HAMAL, NIRĀYANA LONGITUDE, 13^{O} 49’ 30"LATITUDE, 9^{O} 49’ 25.2", DEITY AŚVINAU. AŚVINI, A ARIETIS IS ALSO KNOWN AS HAMAL, THE YOGATĀRĀ OF THE FIRST LUNAR MANSION, COVERS THE NAKṢATRA RANGE OF 0 TO 13^{O} 20$'$. THE STAR IS ALSO REFERRED TO AS 13 ARI, IN THE CONSTELLATION ARIES OR MEṢA, APPARENT MAGNITUDE (V) OF 1.98 TO 2.04, AND IS SITUATED AT A DISTANCE OF ONLY 65 LY.**

Aśvini, which also has the name Hamal, is the brightest star in the constellation Aries. The Hipparchus satellite indicates that α Arietis is about 66 light-years from Earth. It is the 47th brightest star in the night sky and is quite visible to the naked eye. Hamal's orientation with relation to the Earth's orbit around the Sun gives it a certain importance not apparent from its modest brightness. This is a good choice from the point of view of visibility to the naked eye. The vernal equinox occurred in 401 BCE centered on Hamel, with a range of +- 400 years. As a consequence it is assumed that Aśvini was chosen as the first star amongst the Nakṣatra s, since the Sūrya Siddhānta mentions that the VE was in Aśvini when it was being composed. The Aśvins are regarded as the Nasatyas.

The **Aśvins** (Sanskrit: अश्विन *aśvin-*, dual *aśvinau*) are divine twin horsemen in the RV, sons of Saranya(daughter of Vishwakarma), a goddess of the clouds and wife of Sūrya in his form as Vivasvat. They are Vedic gods symbolizing the shining of sunrise and sunset, appearing in the sky before the dawn in a golden chariot, bringing treasures to men and averting misfortune and sickness. They can be compared with the Dioscuri (the twins Castor and Pollux) of Greek and Roman mythology and especially to the divine twins Ašvieniai of the ancient Baltic religion.

They are the doctors of gods and are Devas of Ayurvedic medicine. They are called **Nasatya** (dual *nāsatyau* "kind, helpful" in the Ṛg Veda; later, Nasatya is the name of one twin, while the other is called **Dasra** ("enlightened giving"). By popular etymology, the name *nāsatya* was analyzed as *Na+asatya* "not untrue"="true".

In the epic MBH, King Pandu's wife Madri is granted a son by each Aśvin God and bears the twins Nakula and Sahadeva who, along with the sons of Kunti, are known as the Pandavas.

To each one of them is assigned the number 7 and to the pair the number 14.

Aśvini is the name of an asterism in Indian astronomy, later identified with the mother of the Aśvins. This star is identified as Hamal, the brightest star in the constellation of Aries (α Arietis). The Vernal Equinox occurred in 401 BCE

The Aśvins are mentioned 376 times in the RV, with 57 hymns specifically dedicated to them: 1.3, 1.22, 1.34, 1.46-47, 1.112, 1.116-120, 1.157-158, 1.180-184, 2.20, 3.58, 4.43-45, 5.73-78, 6.62-63, 7.67-74 8.5, 8.8-10, 8.22, 8.26, 8.35, 8.57, 8.73, 8.85-87 10.24, 10.39-41, 10.143. The consequences of the special significance of Aśvini in the Vedic hymns, allows us to make inferences about the date of the RV, which we discuss in the chapter on Astro-chronology.

[97] *Richard Allen “Star names and their Lore and Meaning”, Dover Publications, NY, 1963, first published 1899.*

2. APABHARAṆI, MUSCA, 41 ARIETIS, **24° 21’ 44.1" , 10° 16’ 41.9", DEITY YAMA**

There are 3 choices, none of them ideal. The 3 possibilities for the Yogatārā are 35 Arietis, 41 Arietis, and δ Arietis. If visibility is a criterion, one should select Musca, 41 Arietis δ Arietis is closer to the ecliptic, but is barely visible with the naked eye. The Presiding deity is Yama.

3. KRITTIKA, ALCYONE, η TAURI, THE PLEIADES 36° 7’ 53.9" AND 3° 51’ 10.7", DEITY AGNI

The regent or Deity of the asterism is Agni. The group is collectively known as the Plaiedes**. Alcyon**e is also known as Eta Tauri. The world literature (and the Indic was no exception) is rich in references to Krittika. Krittika was the Nakṣatra in which the vernal equinox occurred in 2220 BCE and hence this is sometimes referred to as the Krittika era in Indic History. The practice of referring to an era by the name of the Nakṣatra in which the vernal equinox occurs was first defined by TILAK in his treatise on ORION where he popularized this naming convention especially since each Nakṣatra lasted for approximately a thousand years, which was an easy number to remember

4. ROHIṆI, ALDEBARAN, α TAURI 45°, 54’, 48.9",-5°, 40’, 51.9", DEITY – PRAJAPATI

Rohiṇi is by far the brightest, and therefore the α star of the constellation Taurus. The ancient name, from Arabic, means "the Follower," as the star seems to follow the Pleiades, or Seven Sisters star cluster, across the sky. Aldebaran, 67 light years away, is positioned in front of the sprawling Hyades star cluster (in mythology, half-sisters to the Pleiades) that make the head of Taurus the Bull, but is not a part of it, the cluster (at 150 light years) over twice as far away. Nevertheless, it makes a fine guide to it. In most renderings of the constellation, Aldebaran makes the celestial Bull's eye. This class K (K5) giant star, of first magnitude (0.85) and 14th brightest in the sky, is a low-level irregular variable star that fluctuates erratically and to the eye unnoticeably by about two-tenths of a magnitude. The Vernal equinox occurred in Rohiṇi in 3247 BCE. Prajāpati is the presiding deity.

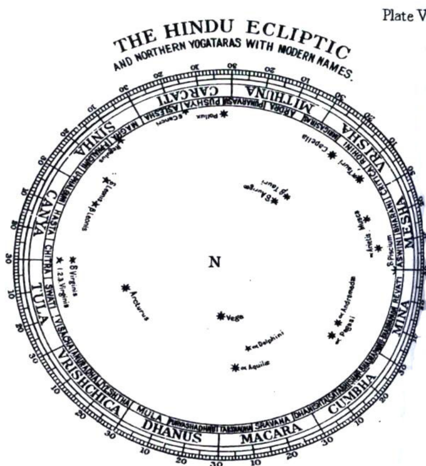


FIGURE 4 & 5 FROM BRENNAND HINDU ASTRONOMY

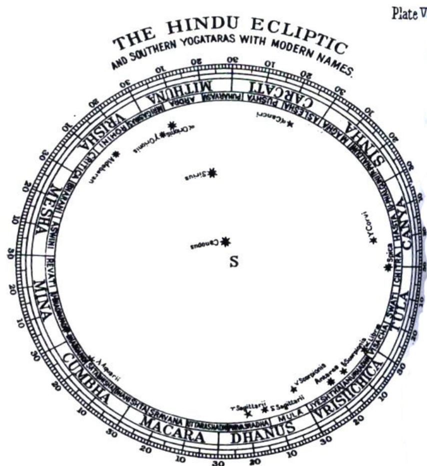


FIGURE 6 THE SOLAR AND SIDEREAL ZODIACS (2000 BCE) THE KRITTIKA ERA DEPICTING THE DIFFERENCE IN THE START OF THE SEQUENCE

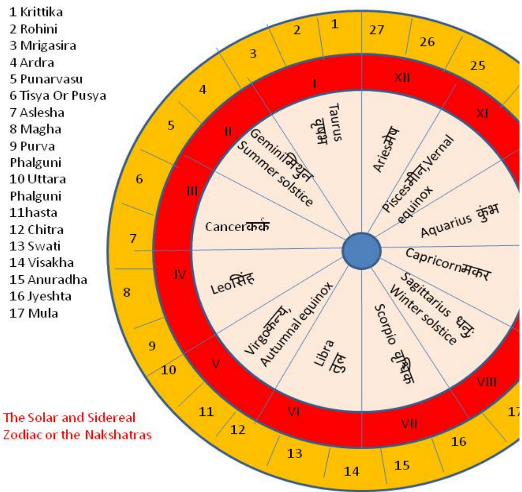


TABLE 7 THE SOLAR ZODIAC AND THE LUNAR MONTH			
Western Zodiac	**Name of Indian Zodiac**	**Name of Lunar month**	**Position in Zodiac(figure 10)**
Taurus, Bull	Vŗşabha	Jyeşţha	I
Gemini, Twins	Mithuna	Ā□ā□hā	II
Cancer, Crab	Karka (Greek Kārkinos)	Srāvaṇa	III
Leo, Lion	Simha	Bhādrapadā	IV
Virgo, Virgin	Kanya	Aśvina	V
Libra, Balance	Tula	Kārtika	VI
Scorpius, Scorpion	Vrushchik	Mārgaśīrşā, Agrahāya□a	VII
Sagittarius, Archer	Dhanu	Pauşa	VIII
Capricornus, Goat horn	Makara	Māgha(note the difference in the spelling from that of the Nakşatra	IX
Aquarius, Water pourer	Kumbha	Phalguni	X
Pisces, fish	Mīna	Chaitra	XI
Aries, ram	Meşa	Vaiśākhā	XII

5. MRIGAŚĪRṢĀ, HEAD OF THE ANTELOPE, B TAURI, ELNATH, 58^{O} 42’ 32.2", 5^{O} 9’ 36.5", DEITY SOMA.

Mrigaśīrṣā plays an important role in RV history and is discussed in detail by Tilak in Orion as well as by Jacobi. Mrigaśīrṣā Nakṣatra is associated with month of Mārgaśīrṣā where, on full moon day, moon will be near Mrigaśīrṣā Nakṣatra. This approximates to month of December. The Zodiac name Vṛṣabha suggests a bull with horns, and Mrigaśīrṣā is the head of the bull. Mrigaśīrṣā has been named **El Nath** by Arabs. If a single star has to be identified as representing Mrigaśīrṣā Nakṣatra, best candidate is 112 β Tauri / ElNath. The distance between Rohiṇi and Mrigaśīrṣā is about 50 minutes corresponding to 12.5 degrees (E-W) not too far from the 13.33 requirement. All the Vṛṣabha stars are within the particular Lune of the Lunar Zodiac. The main dissenting vote against El Nath is that it lies above the celestial equatorial plane, whereas the star identified by Burgess is λ Orionis (Rigel) below the celestial equator, although the actual value does not match the value given in Sūrya Siddhānta

6. ARDRA (ARUDRA), BETELGEUSE, α ORIONIS, 64^o 53’ 9.5", -16^o 15’ 12.3", DEITY RUDRA

Ardra, Betelgeuse (α Orionis) is the sixth star when counting from the first point of Aries. The presiding deity is Rudra. It resides entirely within the sign of Gemini 6^o 40’ to 20$^{o.}$ It has a symbol of a human head. The great star Betelgeuse is one of the two that dominate mighty Orion of northern winter, the other Rigel, the pair respectively also called α and β Orionis. The name Betelgeuse is a corruption of the Arabic "yad al jauza," which means the "hand of al-jauza," al-jauza the ancient Arabs' "Central One," a mysterious woman. For us, it marks the upper left hand corner of the figure of the Greek's ancient hunter (and since he depicted is facing you, his right shoulder). One of the sky's two first magnitude supergiants (the other Antares), Betelgeuse is one of the larger stars that can be seen, indeed one of the larger stars to be found anywhere. Typically shining at visual magnitude 0.7 (ranking 11th in the sky), this class M (M1.5) red supergiant (with a temperature of about 3650 Kelvin) is a semi-regular variable that changes between magnitude 0.3 and 1.1 over multiple periods between roughly half a year and 6 years -- and possibly longer (and of course changing its rank). It is currently the star in whose house, the Summer Solstice occurs. June 20, 2089 CE is the date when both the Sun and Betelgeuse are in conjunction exactly at a RA of 6.

7. PUNARVASU, β GEMINORIUM, POLLUX, 89^o 20’ 11.8", 6^o 28’ 39.4", DEITY ĀDITI

Bharatīya Jyotiṣa Ṣāstra states that each Nakṣatra name corresponds to a group of stars called star mansions or Asterisms. The seventh lunar mansion is named Punarvasu. It resides primarily in the constellation Gemini (20o) and consists of five stars. The last pada of Punarvasu resides in Cancer (3^o 20’). Punarvasu is ruled by Aditi, the Great Mother Goddess. This is the seventh Nakṣatra of the zodiac, spanning from 20°-00' in Mithuna (Taurus) to 3°-20' in Karaka(Cancer).The word Punarvasu is derived from Puna+Vasu, which means return, renewal, restoration or repetition. We have identified Pollux as the Yogatārā of Punarvasu. The concept is that Pollux, also catalogued as β Geminorium (β Gem / β Geminorium), is an orange giant star approximately 34 light-years from Earth in the constellation of Gemini (the Twins). Pollux is the brightest star in the constellation, brighter than Castor (α Geminorium). As of 2006, Pollux was confirmed to have an extra solar planet orbiting it. They are twins only in mythology, these warriors, Pollux fathered by Zeus and divine, Castor mortal, both placed in the sky to allow them to be together for all time.

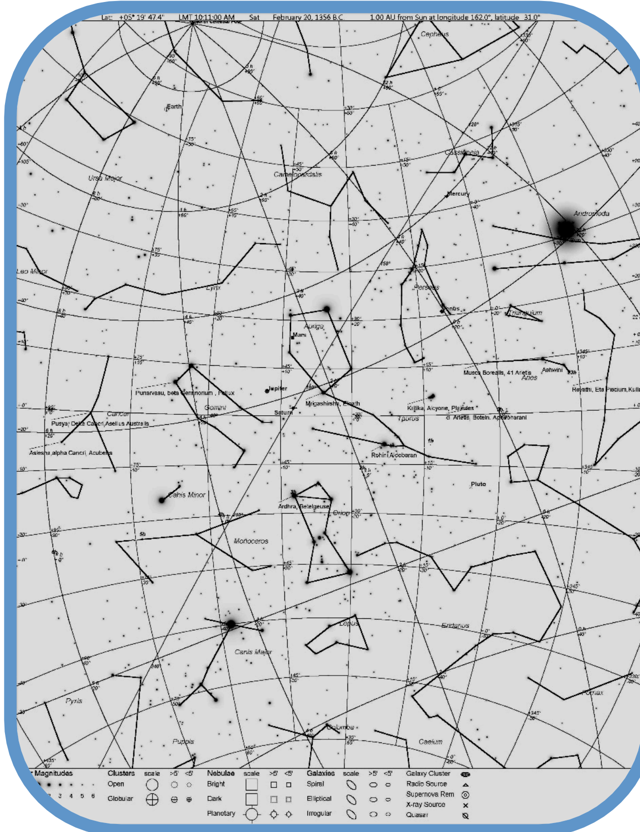
The northernmost of the Zodiacal constellations, Gemini is also among the brightest, helped by first magnitude Pollux and second magnitude Castor. An exception to the rule, brighter Pollux, the sky's 17th brightest star, was given the β designation by Bayer, while somewhat fainter Castor is known as α Geminorium. In fact, Pollux and Castor are nothing like twins, bright Castor a white quadruple star with fairly class. The name Pollux refers specifically to Castor and Pollux, the sons of Leda. The star also bears

Arabic name *Al-Ras al-Tau'am al-Mu'akhar*, literally, 'The Head of the Second Twin' of the Ādityas. The VE occurred in this Nakṣatra in **6050 BCE.**

8. **PUṢYA, पुष्य, Δ CANCRI, ASELLUS AUSTRALIS, 104^{O} 51’ 13.3", 0^{O} 5’ 49.4", DEITY BRHASPATI**

δ Cancri (*δ Cnc / δ Cancri*) is an orange giant star approximately 136 light-years away in the constellation Cancer. It has the traditional name **Asellus Australis** which in Latin means "southern donkey colt". It also has the longest of all-star names "Arkushanangarushashutu" which is still sometimes used. This is derived from ancient Babylonian and means "the southeast star in the Crab". This is sometimes spelt with hyphens as Arku-sha-nangaru-sha-shutu. Since it is near the ecliptic, it can be occulted by the Moon and very rarely by planets.

FIGURE 7 THE SKYMAP FOR FEB 20, 1356 BCE (THE VEDĀṄGA ERA (3000 BCE 800 BCE)



δ Cancri was involved in the first recorded occultation by Jupiter:. The RV mentions Vernal equinox in Puṣya, which attests to a date of 7414 BCE, when Puṣya and the Sun are at 0 RA at the same time. "The most ancient observation of Jupiter which we are acquainted with is that reported by Ptolemy in book X, chap. iii (sic), of the Almagest, .when the planet eclipsed the star known as (δ) Cancri. This observation was made on September 3, BCE 240, about 18h on the meridian of Alexandria." *(From Allen, 1963, quoting from Hind's The Solar System).*

9. **ĀŚLEṢĀ, α CANCRI, ACUBENS, 109^{o} 47’ 15.6", -5^{o} 14’ 29.8", DEITY SARPAH**

α Cancri (α Cnc / α Cancri) is a star system in the constellation Cancer. It has the traditional name **Acubens** (Açubens), more rarely *Al Zubanah,* from the Arabic الزبانة *az-zubānah* "the claws (of the crab)". A less common name is **Sertan**. It is approximately 174 light years from Earth.

The primary component, **α Cancri A**, is a white A-type main sequence dwarf with an apparent magnitude of +4.26. Its companion, **α Cancri B**, is an eleventh magnitude star located 11 arc-seconds away.

Since it is near the ecliptic, it can be occulted by the Moon and very rarely by planets. From studying its light curve during occultation, it is thought that α Cancri A may itself be a close binary, consisting of two stars with similar brightness and a separation of 0.1 arc-seconds. **Āśleṣā** is the name of a daughter of Prajapati Daksha; she is one of the wives of Chandra, in Vedic astrology and is associated with the star ζ Piscium.

10. MAGHA, A LEONIS, REGULUS, 125^{O} 57’ 33.8”, 0^{O} 21’ 15.8”, DEITY PITARAH

Magha is a Nakṣatra in Indian astrology corresponding to the star Regulus. Anurādha is a goddess of good luck. Anurādha is the 17th Nakṣatra Jyeṣṭa. The Eldest (Devanagari ज्येष्ठा) is the 18th Nakṣatra or Lunar mansion in Vedic astrology associated with the heart of the constellation Mūla (The Root Devanagari मूल) is the 19th Nakṣatra or Lunar mansion in Vedic astrology and corresponds to the tail and sting of the constellation Shravana (Devanagari श्रवणा) is the 22th Nakṣatra (Devanagari नक्षत्र) or Lunar mansion as used in Hindu astronomy and Uttara **Bhādrapadā** or Uttarabhādra (Devanagari उत्तराभाद्रा) is the 26th Nakṣatra (Devanagari नक्षत्र) or Lunar mansion Revati रेवती (The Wealthy is the 27th Nakṣatra or Lunar mansion.

11. PŪRVA PHĀLGUNI, δ LEONIS, ZOSMA,137^{o} 23’ 35.8”, 14^{o} 15’ 52.6", DEITY ARYAMAN (BHAGA)

δ Leonis (δ Leo / δ Leonis) is a star in the constellation of Leo. It has the traditional names **Zosma** (or **Zozma**) and **Duhr**. Rare spellings include *Zozca, Zosca, Zubra,* and *Dhur.*

Zosma is a relatively ordinary main sequence star, although it is somewhat larger and hotter than the Sun. It is a fairly well-studied star, allowing for relatively accurate measurements of its age and size. Having a larger mass than the Sun it will have a shorter lifespan, and in another 600 million years or so will swell into an orange or red giant star before decaying quietly into a white dwarf. The name Zosma means girdle in ancient Greek, referring to the star's location in its constellation, on the hip of the lion. The absolute magnitude of Zosma is 1.29 while its apparent magnitude is 2.56. ZOSMA (δ Leonis). A star with two names, one Greek, the other Arabic, and Zosma rides the back of Leo the Lion. Its principal name, by which it is listed here, is from Greek and means "girdle.” It is part of a set of stars that surround us called the "Ursa Major Stream," all of which (including Sirius) share a common motion across the sky. Their physical relation is unclear. Fourth, unlike its neighbor Denebola, Zosma appears to have no surrounding dusty cloud that might be suspected of harboring planets. Finally, Zosma is so well studied that astronomers actually have an age for it. From its current luminosity and temperature (as well as other properties), it is between 600 and 750 million years old. Its mass of 2.2 Solar masses allow a total hydrogen-fusing age of around a billion years (a tenth that of the Sun), so Zosma is well over half way toward beginning its death process, when its then-helium core will contract and its outer layers will expand, making it into an orange giant.

12. UTTARAPHĀLGUNI, β LEONIS, DENEBOLA, 147^{o} 42‘ 1.6", 12^{o} 14‘ 15.4", DEITY, BHAGA (ARYAMAN)

Uttara Phālguni, DENEBOLA (β Leonis) Great Leo, which dominates northern spring skies, contains three stars of note, bright Regulus, second magnitude Algeiba, which shares the "Sickle" with Regulus, and second magnitude (2.14) Denebola. Denebola, Leo's β star, is the easternmost of a prominent triangle of stars set to the east of Regulus. It provides us with the Lion's tail, the name coming from the Arabic

phrase that means exactly that. Denebola is a white class A (A3) dwarf (hydrogen-fusing) star of temperature 8500 degrees Kelvin, and is similar to summer's first magnitude Altair, but at a distance of 36 light years it is twice as far away and therefore dimmer to the eye. Like all the brighter naked eye stars, Denebola is more luminous than the Sun, emitting 12 times the solar energy. It is one of a fairly rare "Vega" class of stars that is surrounded by a veil of infrared- emitting dust. Since the planets of our Solar System were apparently created from a circumstellar dusty cloud, such dust implies the possibility that Denebola might have planets as well, though there is no direct evidence for brightness by small amounts over periods of only hours. The star shows no evidence for any kind of stellar companion.

13. HASTA, γ VIRGINIS, PORRIMA, 166° 15′ 44", 2° 50′ 2.2", DEITY SAVITAR

Hasta, PORRIMA (γ Virginis). Follow the curve of the handle of the Big Dipper to the south as it first passes through orange Arcturus and then south of the sky's equator through blue-white Spica. Just up and to the right of Spica lies dimmer, third magnitude Porrima, Virgo's γ star (or γ Virginis). Unlike most star names, which are Arabic, this one is Latin and honors a Roman goddess of prophecy. A telescope shows a remarkable sight, one of the finest double stars in the sky. The components are almost perfect identical twins, both white stars with surface temperatures of about 7000 degrees, significantly warmer than the Sun. They orbit each other on highly elliptical paths in only 170 years, and as a result, a single observer can watch them easily move over the course of a lifetime. They are now about 3 seconds of arc apart, and will make their closest approach to each other in the year 2007. Thirty- eight light years away, the stars average 40 astronomical units from each other, about the distance between the Sun and Pluto. Both stars, like the Sun, belong to the "main sequence," that is, they radiate as a result of the fusion of internal hydrogen into helium. They are each about 50 percent more massive than the Sun, which results in their higher surface temperatures and in luminosities about four times Solar.

14. CHITRA, β VIRGINIS, SPICA, 179° 58′ 48.8",-1° 57′ 33.9", DEITY INDRA (TVASTR)

Chitra, SPICA (α Virginis). Spica, the luminary of Virgo, becomes prominent in the southeast in northern spring evenings, and can easily be found by following the curve of the Big Dipper's handle through Arcturus and then on down. Though a large constellation, Virgo, the Virgin, does not have much of any prominent stellar pattern, relying on Spica to tell us where it is. The star lies about 10 degrees south of the celestial equator, and practically on the ecliptic, the path of the Sun, and is regularly occulted, or covered over, by the Moon. The Sun passes Spica in the fall, rendering the star a harvest symbol that is reflected in its name, from Latin meaning "ear of wheat," the name actually going back to much more ancient times. Though at a distance of 250 light years (second Hipparcos reduction), Spica is still first magnitude (1.04), showing its absolute brilliance, the star visually 1900 times more luminous than the Sun. The apparent brightness is deceptive, however, as Spica actually consists of two stars very close together (a mere 0.12 Astronomical Units apart) that orbit each other in slightly elliptical paths with a period of only 4.0145 four days, which makes them difficult to study individually.

15. SVĀTĪ, π HYDRAE, 49, HYDRAE, 194° 47′ 38.6", -12° 54′ 18.4", DEITY VAYU

Svāti (pronounced Svātī with a lengthened 'a' and 'i' is a Nakṣatra in Hindu Astronomy, Has been associated with the star Arcturus. Meaning: Sword or Independence.

Western star name: Arcturus, Lord: Rahu (ascending lunar node), Symbol: Shoot of plant, coral, Deity: Vayu, the Wind god.

Indian zodiac: 6°40' - 20° Tula; Western zodiac 2°40' - 16° Scorpio

16. VIṠĀKHĀ, β LIBRAE, ZUBENESCHAMALI , 205° 28′ 47.4" , 8° 40′ 13", DEITY INDRAGNI

β Librae (β Lib / β Librae) is the brightest star in the constellation Libra. It has the traditional name **Zubeneschamali** and the Latin name **Lanx Australis** ("the southern scale [of the Balance]"). The name ***Zubeneschamali*** is derived from the Arabic, *al-zuban al-šamāliyyah* meaning "The Northern Claw". β Librae is a blue dwarf star of spectral type B8 (main sequence star), a little less evolved than Sirius. It has apparent magnitude 2.7.

At a distance of 160 light years from Earth, it is about 130 times more luminous than the Sun and has a surface temperature of 12,000 K, double that of the Sun. This high temperature produces light with a simple spectrum, making it ideal for examining the interstellar gas and dust between us and the star. Like many stars of its kind, it is spinning rapidly, over 100 times faster than the Sun. This type of hydrogen-fusing star often appears blue-white, but β Librae is often described as greenish, the only greenish star visible to the naked eye.

17. ANURADHA, δ SCORPII, 218° 42' 16.2", -1° 46' 59.9" .DEITIES MITRA RADHA

δ Scorpii (δ Sco / δ Scorpii) is a star in the constellation Scorpius. It has the traditional name Dschubba (or **Dzuba**, from Arabic *jabhat*, "forehead" (of the scorpion)) or also **Iclarcrau** or **Iclarkrav**. Because δ Scorpii is near the ecliptic it is occasionally occulted by the Moon, or (extremely rare) by planets. In June 2000, δ Scorpii was observed by Sebastian Otero to be 0.1 magnitudes brighter than normal. Its brightness has varied since then and has reached as high as magnitude 1.6 or 1.7, altering the familiar appearance of Scorpius. Spectra taken after the outburst began have shown that δ Sco is throwing off luminous gases from its equatorial region. As of 2005 the flare-up continues. Although the brightness varies, it remains well above its previous constant magnitude.

18. JYEṢṬHA, α SCORPII, ANTARES, 225° 53' 53.1", -4° 21' 22.2", DEITY INDRA (VARUNA)

Jyeṣṭha ANTARES (α Scorpii). A brilliant jewel set within the Milky Way, Antares guides us to one of the great constellations of the sky, the Zodiac's Scorpius (or Scorpio), the celestial scorpion, one of the few constellations that actually looks like what it represents. Antares, a class M (M1.5) red supergiant gleaming red at the scorpion's heart, has a color similar to Mars. Since it is found within the Zodiac, which contains the apparent path of the Sun and planets, it is commonly mistaken for the red planet, a fact shown by its name, Antares, or "Ant-Ares," which means "like Mars," "Ares" being the Greek name for the god of war. This magnificent first magnitude (typically 0.96) star, shining opposite Betelgeuse, its counterpart in Orion, is ranked the 15th brightest in the sky. It is, however, a semi-regular variable that can change by several tenths of magnitude over a period of years. Its great distance of 550 light years (second Hipparcos reduction) reveals that it is truly luminous, to the eye almost 10,000 times brighter than the Sun. Because it is cool, only about 3600°K (Kelvin) at its surface, it radiates a considerable amount of its light in the invisible infrared. When that is taken into account, the star becomes some 60,000 times brighter than the Sun (with considerable uncertainty).

19. MŪLA, λ SCORPII, SHAULA, 240° 43' 11.7", -13° 33' 45.6", DEITY PITARAH

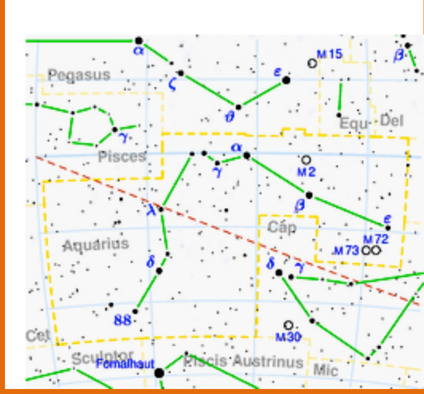
LAMBDA SCORPII (**λ SCO / λ SCORPII**) is the second brightest star system in the constellation Scorpius, and one of the brightest stars in the nighttime sky. It has the Bayer designation λ despite being the second brightest in its constellation. It has the traditional name **Shaula**, which comes from the Arabic *al-šawlā´* meaning *the raised [tail]*, as it is found in the tail of the scorpion (Scorpius). It is known as the Eighth Star of the Tail in Chinese.

Lambda Scorpii is a multiple star with three visible components. The first, **Lambda Scorpii A**, is classified as a B-type subgiant. The 15th magnitude **Lambda Scorpii B** has a separation of 42 arc-seconds from component A, while the 12th magnitude **Lambda Scorpii C** is 95 arc-seconds from A. It is not known whether or not these components are physically associated with component A. If they both were, B would be approximately 7500 Astronomical Units and C approximately 17,000 AU (0.27 light years) from A. Its distance is 112±5 parsecs.

20. PŪRVA ĀṢĀDHA, δ SAGITTARII, KAUS MERIDIONALIS, 250° 42’ 30.2”, -6° 154’ 48.6" DEITY ĀPAH

δ Sagittarii (δ Sgr / δ Sagittarii) is a star system in the constellation Sagittarius. It has the traditional names **Kaus Media**, **Kaus Meridionalis**, and **Media**. Kaus Media is 306 light years from Earth and radiates with a total luminosity of 1180 times that of the Sun. The radius of Delta Sgr is 62 times Solar while its mass is about 5 times the solar mass. Kaus Media has an apparent magnitude of +2.72 and belongs to the spectral type K3. It has three dim companions: **δ Sagittari B**, a 14th magnitude star at a separation of 26 arc-seconds, **δ Sagittarii C**, a 15th magnitude star at a separation of 40 arc-seconds, and **δ Sagittarii D**, a 13th magnitude star at a separation of 58 arc-seconds from the primary. It is not certain that these stars form a physical system or whether they are merely aligned by chance. In the Hindu system of Astrology, this star is also called "***Pūrva Āṣādha Nakṣatra***". In ancient Chinese astronomy, it is the 4th star of 6 stars in the Dipper or 'South Dipper' mansion of the Black Tortoise of the North. The name Kaus Media comes from the Arabic قوس *qaws* 'bow' and Latin *media* 'middle'.

FIGURE 8 λ AQUARII, SATABHISAJ



21. UTTARA ĀṢĀDHA, τ SAGITTARII, 260° 57’ 31.8", -4° 52’ 15.5", DEITY VISVEDEVAH

τ Sagittarii (τ Sgr / τ Sagittarii) is a star in the constellation Sagittarius, 120 light years **from Earth. It also has the traditional name Hecatebolus (Greek Εκατηβολος), which was an alternate** name for the god Apollo as the "Far Darter" or "Sharp-shooter", the god of sudden death. In ancient Chinese astronomy, it is the 5th star of 6 stars in the Dipper or 'South Dipper' mansion of the Black Tortoise of the North. It is a spectral type K1 or K2 giant and has an apparent magnitude of +3.32. It is slightly cooler than our Sun, of a light orange color.

22. ŚRĀVAṆA, β CAPRICORNUS, 280° 11’ 16.8", 4° 46’ 26.7" Deity Viṣnu

β Capricorni (β Cap / β Capricorni) is a star system in the constellation Capricornus. It has the traditional name **Dabih**, which comes from the Arabic *al-dhābih,* meaning "the butcher". The β Capricorni system is located 328 light years from Earth. Because it is near the ecliptic, β Capricorni can be occulted by the Moon, and also (rarely) by planets. With binoculars or a small telescope, β Capricorni can be resolved into a double star. The brighter of these two components, β^1 Capricorni or Dabih Major, has an apparent magnitude of +3.05, while the dimmer one, β^2 Capricorni or Dabih Minor, has an apparent magnitude of +6.09. The two components are separated by 3.5 arc-minutes on the sky, putting them at leapt 21,000

AU (0.34 light years) apart. They take approximately 700,000 years to complete one orbit. Both of these components are themselves made up of multiple stars. Due to the complexity of this system, several different schemes have arisen to denote the subcomponents. This article follows the naming used in the Multiple Star Catalogue.

23. DHANISHTA, SRAVISHTA, δ CAPRICORNUS, DENEB ALGEIDI , 299^{O} 39’ 51.6", -2^{O} 28’ 12.8", DEITY VASAVAH

δ Capricorni is the brightest star of the constellation (as well as an eclipsing binary). The Arabs called delta and nearby gamma Capricorni "The Two Friends". This was suggested by Prof Achar[98] instead of β Delphini. In any event the range of dates for the VJ lies between 1330 BCE (β delphini) and 1861 BCE (δ Capricorni**)**. As the Sun leaves the winter solstice and Sagittarius behind, it moves into its next Zodiacal station, Capricornus, the "water goat, and in early February crosses between the figure's head and tail**. δ Capricorni** is called Deneb Algedi, from the Arabic for ‘the kid's tail'. The tropic of Capricorn is at the latitude on Earth at which the Sun appears overhead at noon on the winter solstice, around December.

24. SATABHISAJ, λ AQUARII, 317^{O} 42’ 17.1", - 0^{O} 19’ 7.5", DEITY VARUNA

Lambda Aquarii (λ Aqr / λ Aquari) is a star in the constellation Aquarius. It has the obscure traditional names Huydor and Ekkhysis, from the ancient Greek *‘υδωρ* "water" and *εκχυσις* "outpouring". Lambda Aquarii is an M-type red giant with a mean apparent magnitude of +3.73.

It is approximately 392 light years from Earth. It is classified as an irregular variable star and its brightness varies from magnitude +3.70 to +3.80. The star's location in the sky is shown in the following map of the constellation Aquarius :

25. PŪRVA BHĀDRAPADĀ, MARKAB, α PEGASI, 329^{O} 41’ 42", 19^{O} 25’ 39.7", DEITY AJA EKPAD

Bhādrapadā is from Bhadra “beautiful, happy” and pada – foot. Again **Pūrva** and Uttara mean former and later. Four stars make the Great Square of Pegasus, Markab (α) at the southwestern corner, Scheat (β) at the northwestern, Algenib (γ) and the southeastern, and Alpheratz (α Andromedae) at the northeastern, this last star linking the Winged Horse to Andromeda. "Markab" comes from an Arabic phrase meaning "the horse's shoulder," but in more recent times was mistakenly taken from what is now Scheat. But Scheat's name ("the shin" was mistakenly taken from "Skat," the δ star in Aquarius. Continuing the confusion, Algenib's name was taken from Mirfak (the Star in Perseus), whose alternative name is ALSO Algenib. Not to be outdone, "Alpheratz" may have come from an original name for Scheat. The Greek letter system is not much better. As a linking star, Alpheratz -- α Andromedae -- is also δ Pegasi. Moreover, Mirfak, the α star, just barely second magnitude (2.49), is only third brightest in the constellation, and is exceeded by both the β star (Scheat), by of all things, Epsilon (Enif), as well as by the δ star (Alpheratz of Andromeda).

26. UTTARA BHĀDRAPADĀ, ALGENIB, (उत्तरभाद्रपदा), Γ PEGASI, 345^{O} 20’ 14.8”, 12^{O} 33’ 35.9", DEITY AHIRBUDHNYA

[98] *Narahari Achar, BN “In search of Contemporary views on Indian civilization” , Proceedings of the Waves conference held in Hoboken, NJ, 2000, edited by Bhudev Sharma*

The other alternatives **are α Andromeda**, which is a poor choice, since it is very far from the ecliptic. The deity is Ahirbudhnya. **γ Pegasi** (γ Peg) is a star in the constellation of Pegasus. It also has the traditional name **Algenib**; confusingly however, this name is also used for α Persei. It is known as the First Star of the Wall in Chinese. γ Pegasi is a β Cephei variable star that lies at the lower left-hand corner of the Great Square of Pegasus. Its magnitude varies between +2.78 and +2.89 with a period of 3.6 hours. It is 335 light-years distant and belongs to spectral type B2. It has a total luminosity of 4000 times that of the Sun with a radius of 4.5 times Solar. The mass of γ Pegasi is 7 to 10 solar masses.

27. REVATI, H PISCIUM, 2^{O} 58’ 8.5” , 5^{O} 16’ 19.3”, DEITY PUSAN

Revati means wealthy, abundant and its presiding divinity is Pushan, one of the Ādityas. The junction star is said to be the southernmost star that is closest to the ecliptic. However the star Zeta Piscium which is usually mentioned is a very faint star causing Al Biruni to be rather caustic in his remarks that the Brāhmaṇas who fancy themselves to be rather adept at observational astronomy were not able to point to the first star in the Lunar Zodiac, But the ancients may not have intended the Yogatārā to be Zeta Piscium. A more likely candidate appears to be Eta Piscium, Kullat Nunu (indicates this star was known to the Baylonians) see the relevant sky chart and has brightness of 3.63 which is certainly a lot more visible than zeta Piscium. The longitude difference between the 2 stars is 7^{o} which is unfortunately not negligible, and could make a difference of 500 years. However, there are no better choices in the Longitude range between 330 and 345 degrees, which only goes to show that there is a lot to be said for randomness, at least in the placement of the stars around the ecliptic.
Between 2000 and 100 BCE, the apparent path of the Sun through the Earth's sky placed it in Aries at the vernal equinox, the point in time marking the start of spring. This is why most astrology columns in modern newspapers begin with Aries. While the vernal equinox has moved to Pisces since then due to precession of the equinoxes. Hamal has remained in mind as a bright star near what was apparently an important place when people first studied the night sky.

THE CURIOUS STORY OF THE SAPTARIṢI

The table 8 provides the modern astronomical identity of the nine stars from *Vedic* period, not in the ecliptic track. The 27 daily stars are in ecliptic plane. *Dhruva* (Polaris) is not illustrated in any of the figures, as its identity is very well known in the sky. One of the calendric systems used in ancient India is the Sapta Riṣi Yuga, named after the Great Riṣis of yore.

At the beginning of the process of creation, Brahma created eleven *Prajapatis* (used in another sense), who are believed to be the fathers of the human race. The *Manusmriti* enumerates them as *Marichi*, *Atri*, *Angirasa*, *Pulastya*, *Pulaha*, *Kratu*, *and Vaśiṣṭa. Prachetas* or *Daksha*, *Bhrigu*, and *Narada*. He is also said to have created the seven great sages or the saptariṣi to help him create the universe. However since all these sons of his were born out of his mind rather than body, they are called *Manas Putras* or mind-sons.

NAMES OF THE SAPTARIṢI

In the post-Vedic period a Manvantara is the period of astronomical time within an aeon or Kalpa, a "day (day only) of Brahma"; like the present *Śveta Vārāha Kalpa*, where again 14 Manvantaras add up to create one Kalpa. Each Manvantara is ruled by a specific Manu, apart from that all the deities, including Víṣṇu and Indra; Rishis and their sons are born anew in each new Manvantara, the Víṣṇu Purāṇa mentions up to seventh Manvantara.

First Manvantara - the interval of **Swayambhu Manu**
Marichi, Atri, Angiras, Pulaha, Kratu, Pulastya, and Vaśișța.
Second Manvantara - the interval of **Swarochisha Manu**
Urja, Stambha, Praṅa, Dattoli, Rishabha, Nischara, and Arvaríva
Third Manvantara - the interval of **Uttama Manu**
Sons of Vaśișța.: Kaukundihi, Kurundi, Dalaya, Śankha, Praváhita, Mita, and Sammita.
Fourth Manvantara - the interval of **Támasa Manu.**
Jyotirdhama, Prithu, Kavya, Chaitra, Agni, Vanaka, and Pivara.
Fifth Manvantara - the interval of **Raivata Manu**
Hirannyaroma, Vedasrí, Urddhabahu, Vedabahu, Sudhaman, Pārjanya, and Mahámuni.
Sixth Manvantara - the interval of **Chakshusha Manu**
Sumedhas, Virajas, Havishmat, Uttama, Madhu, Abhináman, and Sahishnnu.
The present, seventh Manvantara - the interval of Vaivasvata Manu
There are many contradictory lists of the names of the Saptarișі. These usually include Atri, Kashyapa, and Vaśișța, but the other four are varying. One such list is used in the Sandhyāvandanam : Atri, Bhrigu, Kautsa, Vaśișța., Gautama, Kashyapa and Angirasa. Other lists include Vișvāmitra and Jamadagni. The exact list of Saptarișis is not perfectly known as it is supposed that the links to the hierarchy were lost in medieval India due to the effects of Kaliyuga.

OTHER RIȘIS NAMED IN THE VEDA

Four Kumaras • Agastya • Agnivesa • Aruni • Aștāvakra • Astika • Atharvan • Atreya • Aupamanyava • Aurava • Bhrigu • Bhringi • Brahmarshi • Chyavana • Dadhichi • Deale • Dīrghatamas • Dūrvasa • Garga • Gritsamada • Jahnu • Jaimini (Mīmāmsa) • Kambhoja • Kambu Swayambhuva • Kanada (Vaisheshika) • Kanvas • Kanwa • Kapila (Saṇkhya) • Kindama • Kutsa • Maṇdavya • Markandeya • Nachiketa • Narada • Paraşara • Radars • Rishyasringa • Sandipani • Sankrithi • Shringi Rişi • Shukra • Suka • Upamanyu • Vadula • Vaisampayana • Vālmīki • Vartantu • Vibhandak Rişi • Vyasa (Vedas, Vedanta) • Yājnavalkya.

Legend has it that the Sarasvat Brāhmaṇas used to reside along the banks of the Sarasvati. Use of the saptarișі cycle appears to be simultaneous with the appearance of the Sarasvat Brāhmaṇas or Kashmiri Pandits, who were one branch of the general emigration out of the area.

The following is based on an Analysis by Dr. Satya Prakash Saraswat[99]
The saptarișі reckoning is used in Kashmir, and in the Kangra district and some of the Hill states on the south-east of Kashmir; some nine centuries ago it was also in use in the Punjab, and apparently in Sind. In addition to being cited by such expressions as Saptarshi-samvat. It is found mentioned as Lokakala, "the time or era of the people," and by other terms which mark it as a vulgar reckoning. And it appears that modern popular names for it are Pahari-samvat and Kachcha-samvat, which we may render by "the Hill era " and " the crude era." The years of this reckoning are lunar, Chaitradi; and the months are Pūrnimanta (ending with the full-moon). As matters stand now, the reckoning has a theoretical initial point in 3077 BCE and the year 4976, more usually called simply 76, began in CE. 1900; but there are some indications that the initial point was originally placed one year earlier.

[99] *Saraswat, Satya Prakash Mahābhārat: An Astronomical Proof from the Bhāgavat Pura006 http://www.hindunet.org/hindu_history/ancient/mahabharat/mahab_sarasvat.html*

In practice, however, it has been treated quite differently. According to the general custom, which has distinctly prevailed in Kashmir from the earliest use of the reckoning for chronological purposes, and is illustrated by Kalhana in his history of Kashmir, the Rājataraṅgiṇi, written in CE 1148-1150, the numeration of the years has been centennial; whenever a century has been completed, the numbering has not run onto, 102, 103, &c., but has begun again with I, 2, 3, &c.

There was a belief that the Saptarişi, " the Seven Rişis or Saints," Marichi and others, were transformed and became the stars of the constellation Ursa Major, in 3076 BCE (or 3077); and that these stars possess an independent movement of their own, which, referred to the ecliptic, carries them round at the rate of 100 years for each Nakşatra or twenty-seventh division of the circle. Theoretically, therefore, the saptarişi reckoning consists of cycles of 2700 years; and the numbering of the years should run from 1 to 2700, and then commence afresh.

The belief underlying this reckoning according to the course of the Seven Rişis is traced back in India, as an astrological detail, to at least the 6th century CE But the reckoning was first adopted for chronological purposes in Kashmir and at some time about CE 800; the first recorded date in it is one of " the year 89," meaning 3889, = CE 813-814, given by Kalhana. It was introduced into India between CE 925 and 1025. These astronomical observations about the positions of the Saptarişis (Ursa Major) and some predictions based on their movement are contained in the second chapter of the twelfth Canto of the Bhāgavata Purāṇa. In relating the story of lord Kṛṣṇa's life to king Parikshit, the grandson of Arjuna, Rişi Shukdeva explains:

FIGURE 9 WINTER SOLSTICE IN AŚVINI, ALPHA ARIETIS,

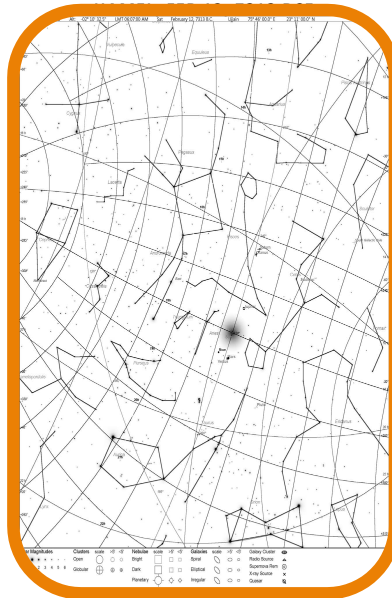


TABLE 8 THE SAPTA RIȘI					
Vedic Name	Arab name	Bayer identity	Henry Draper	SAO	Brightness
Marichi	Alkaid	85 η UMa	HD 120315	44752	1.86
Vaśiṣṭa.	Mizar	79 ζ UMa	HD 116656	28737	2.27
Angirasa	Alioth	77 ε UMa	HD 112185	28553	1.77
	Megrez	69 δ UMa	HD 106591	28315	3.31
Pulasthya	Phecda	64 γ UMa	HD 103287	28179	2.44
Pulāha	Merak	48 β UMa	HD 95418	27876	2.37
Kratu	DuBhe	50 α UMa	HD 95689	15384	1.79
Arundhati	Alcor	80 UMa	HD 116842	308	4.01
Dhruva	Polaris	1 α UMi	HD 8890	28751	2.02

Saptarishinam tu yau Pūrvau dṛshyete uditau divi |
Tayostumadhye Nakṣatram dṛshyate yat samam nishi || 27 ||
सप्तरिशिनाम् तु यौ पुर्वौ द्रस्ह्यॆतॆ उदितौ दिवि ।
तयॊस्तुमध्यॆ नक्स्हत्रम् द्रस्ह्यतॆ यत् समम् निस्हि ॥ २७ ॥

One translation: When the constellation of the seven sages (Ursa Major, the Great Bear) rises, the first two of them (Pulaha and Kratu) are seen in the sky. In between them on the same line [northwest] seen in the night sky is their [ruling] lunar mansion. The sages [the stars] connected remain with that lunar mansion for a hundred human years. Now, in your time, are the twice-born situated in the Nakṣatra called Magha. (29) With Víṣṇu, the Supreme Lord, the sun known as Krishna having returned to heaven, this world has entered the age of Kali in which people delight in sin.

Tenaita riśayo yuktastiśthantyabdaśanta nranama |
Tey tvadiye dwijaha kale adhuna charshita maghaha || 28 |
तेनैत रिशयो युक्तस्तिश्थन्त्यब्दशन्त न्रनम ।
तेय् त्वदिये द्विजह कले अधुन चर्शित मघह ॥
Alternate translation: "When the Saptariṣis (the constellation of Ursa Major) rise in the east, only two stars are visible at first. In the middle of two stars, one of the lunar mansions (Nakṣatra) appears on the opposite side of the sky. The seven Riṣis stay with this lunar mansion (asterism) for hundred earth years. Parikshit! From the time of your birth to the present time, they have been positioned with the 'Magha 'Lunar mansion".

An unavoidable question that arises from this modified interpretation is why have the conclusions of Max Müller remained so widely accepted for more than a hundred years? There are two possible reasons for it. First, most astronomers work with expensive telescopes in sophisticated observatories located primarily in advanced industrialized countries and are not familiar with the observations recorded in the Purāṇas or Upanishads. They are also hampered by a lack of mastery of the Indic idiom and the Sanskrit language.

The relative movement of Saptariṣis through twenty three mansions implies that the observations described in the Bhāgavata Purāṇa must have been made either around 300 BCE, or 3000 BCE, since the

positions of the Saptariṣis repeat every 2700 years. The possibility of these observations in 300 BCE can be completely ruled out because the period around 300 BCE is a matter of recorded history. The most logical conclusion that can be drawn from these descriptions is that the astronomical observations described in the Bhāgavata Purāṇa were probably made approximately 5000 years ago, an entire cycle of Saptariṣis before the reign of Chandragupta. The position of the Saptariṣi in Magha during the time of MBH is thus in complete agreement with the estimate of approximately 3000 BCE given by Āryabhaṭa. It is extremely likely that Max Müller's conclusions about astronomy of the Bhāgvata Purāṇa being "imaginary" were based on a questionable interpretation of the direction of movement of the Saptariṣis.

Another reason, perhaps far more important than the previous one, has also prevented a critical scrutiny of Max Müller's arguments. Our knowledge of astronomy was extremely limited at the time of Max Müller but in the past 100 years it has advanced by leaps and bounds with the availability of large optical and radio telescopes and dedicated scientists. There are now convincing answers available to the question why the Saptariṣis change their positions. According to the New Atlas of the universe by Patrick Moore, five of the seven stars of the Saptariṣis (the Plough of Ursa Major) are travelling through the space in the same direction while other two, Alkaid and Dubhe, are moving in opposite direction. Consequently, after a sufficiently long time as a result of the proper motion of the stars the plough tends to lose its characteristic shape and the perpendicular line drawn from the midpoint of Merak and Dubhe crosses the ecliptic at different lunar mansions, changing 3.6 degrees of arc in a century. There is still no scientific explanation of why every 2700 years this movement should repeat but a clue can be found in the work of Anthony Aveni, the noted author of a recent book titled "The Empires of Time: Calendars, Clocks and Cultures". According to this book, there is a widespread belief in many African and American Indian cultures that the entire Solar system revolves in our galaxy[100] the Milky Way, around the brightest star in the Pleiades. The cluster of Pleiades, in the Taurus constellation, is known as the Seven Sisters or "Krittika" in Hindu astronomy. The brightest star in the Pleiades is Alcyone and the Sun completes one revolution around this star in approximately 3000 years. There are no astronomical maps available to verify this observation and no scientific computations can prove or disprove this theory easily but this widespread belief has made Pleiades one of the most sacred objects in the sky in practically every country and culture. This periodic revolution could be the reason why the Saptariṣis repeat the positions described in the Bhāgvata Purāṇa, every 2700 years.

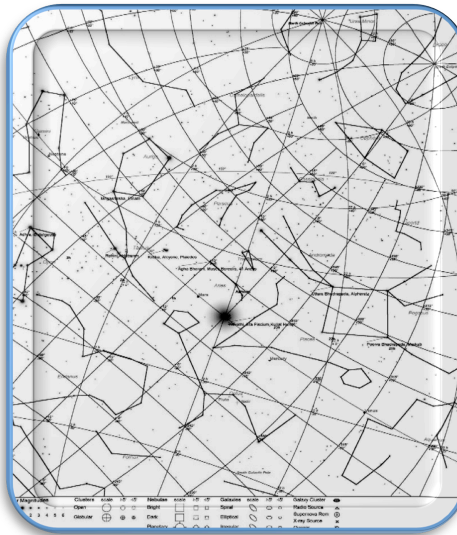


FIGURE 10 VE IN AŚVINI, ALPHA ARIETIS, HAMEL,

MAR 25. 401 BCE

Carl Sagan, a renowned astronomer at Cornell University, who hosted the public television series "Cosmos" in 1985, pointed out that the Hindus were the only ones who came anywhere close to correctly estimating the real age of the universe. But the occidental Indologist, trained as he is to be pathologically skeptical of any

[100] *Also refer to Atharva. Kanda 14 and Yajurveda Chap 3 and 33*

achievements of the ancient Indic, dismisses this as mere coincidence, without even deigning to examine the rationale by which the ancient Indic has arrived at this result. Unlike many cultural traditions that treat science and religion as antithetical to each other, the Hindu tradition encourages the study of physics and metaphysics both for a comparative understanding of the true nature of the cosmic mystery surrounding and pervading the universe. But to concede this would be to admit that the Indic was endowed with a higher degree of rationality all along. It would be especially embarrassing to admit to the necessity of an age of enlightenment to break himself loose from the stranglehold of religious dogma.

The observations recorded in the Bhāgvata Purāṇa thus present a challenge to the modern astronomer to re-establish the connection between the diversity of what the scientists call "Phenomenon" and the underlying spiritual unity of what the renowned German philosopher Immanuel Kant called the "Noumenon". Aniket Sule, Māyank Vahia et al[101] have demonstrated that the visit of the Saptariṣi to different Nakṣatra may be a very significant observation. The transition however, is not time invariant (according to their findings) since it depends on the proximity of the saptariṣi to the north pole which changes due to the Earth's precession and does not appear, at first blush to be a good candidate for calibrating a clock or calendar.

I have not succeeded in coming up with a geometrical construction that indicates the use of the Saptarishi as a pointer to different nakṣatra every hundred years and this remains an unanswered question in my mind, which needs further research.

Chapter 14 and 15 of Dr.Veda Vyāsa's Astronomical Dating of the MBH war, contains several examples where the Sapta Riṣi cycle was used to cross check other calculations.

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[101] *Sule, Aniket ., "Saptarişi's visit to different Nakşatra", ABORI, 2006*

CHAPTER III

HISTORICAL PERSPECTIVES PART I THE VEDIC HERITAGE

In this chapter and the next we will traverse the path of the Indian (Hindu) calendar through the ages from antiquity till the present. This also happens to be in large part the story of Indic astronomy, for the simple reason that calendrical considerations and Positional Astronomy were the primary motivations in the endeavors of the ancient Indic as he sought to decipher the heavens in search of order and periodicity. The oldest calendar is probably the Vedic calendar among the languages referred to as Indo European Languages; at first lunar, later with Solar elements added to it. The sister **Avestan** calendar is similarly first lunar, but later only Solar. Both these calendars (the oldest in the Indo-European universe) are influenced by the prehistoric calendars of the first and second root human species, as they reckon with days and nights lasting six months. The history of astronomy In India has a well delineated timeline, until the Occidental decided to reconstruct this history to suit his own prejudices. We quote Emmeline Plunkett[102]:

"Not much more than a hundred years ago, the Sanskrit language began to yield to the study of the Europeans some of its literary treasures. Almost on the moment a controversy arose as to the antiquity of the science of astronomy. For scholars were amazed to find in this already long dead language many learned astronomical treatises, besides complete instructions for calculating , year by year, the Hindu calendar, as also for calculating horoscopes. "

However, the controversy remains an artificial one, mainly created by Occidental Indologists who did not wish to see India endowed with an antiquity greater than that of Greece. .Shortly thereafter, the opinion of Indian astronomy changed rapidly, with the exception of a handful of individuals, for the worse. The list of detractors of Indian astronomy was and is long and includes names like Weber, Bentley, Winternitz, Biot, Thibaut, and Whitney, constituting almost the entire bunch of historians in the English speaking world, including GR Kaye, Neugebauer, Van der Waerden, and Pingree. There were fence sitters like Burgess, Bühler, and Billard. The unequivocal exceptions were Playfair, Brennand, Bailly, Plunkett, and Jacobi. What is particularly interesting is in many of these cases they continued to spend enormous amounts of time and energy on the study of the Indic texts. In other words their actions were often inconsistent or cognitively dissonant with their own stated views on the matter. Which leads me to wonder why these historians felt compelled not only to refrain from abandoning the study of the manuscripts but to spend an entire lifetime in this pursuit in spite of the fact that they did not have a high opinion of it? One would have assumed that they had better things to do than to pore over a 'regurgitated version of mathematics from Babylon and Greece'. We have pondered on the reasons for the steady deterioration in the reputation of the ancient Indic episteme and we have come up with the following;

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[102] *Emmeline Plunket " Astronomy in the RV", reprinted by Kessinger Publications*

There is a strong tendency to extrapolate the current status of the Indic backwards in time and ascribe superficial assessments to the ancient era. Thus it is easy to fall in the trap of assuming that since the current day Indic is poverty stricken and does not have access to higher education that it was always thus. As a consequence, there is widespread incredulity that the ancestors of the present day Indic, could have come up with world class developments such as *Pāṇini* 's grammar and the highly accurate astronomical measurements which were unrivalled in the ancient world. It is therefore easy for the Occident to belittle the achievements of the ancient Indic, and try to chip away at the uniqueness and antiquity of the Indic civilization in myriad ways, resulting in such non sequiturs as the Āryan Invasion theory.

Further the Occident refuses to acknowledge that there has taken place an epistemic rupture of vast proportions in the Indian subcontinent initiated in large part by the Educational policies of the Colonial Overlord. The consequences include the very real danger, that the Indic is setting himself up for an epistemic discontinuity that may be irreversible. At this point in time it is too early to issue a verdict on whether the epistemic rupture has dealt a fatal blow to the Indic tradition or whether the Indic civilization will be able to synthesize the Occidental episteme without losing its unique identity. All we can say is that Macaulay would not have cause to be unhappy with what he has wrought.

We have quoted Neugebauer (ON) extensively in the prologue where we found ourselves in agreement with him on his general remarks regarding Mathematical Astronomy. But what is interesting is his view on the development of Astronomy in India. ON is the Professor who contributed much to the history of mathematical astronomy.

Quote " *I think it is fair to say that practically all fundamental concepts and methods of ancient astronomy, for the better or the worse, can be traced back either to Babylonia or Greek astronomers. In other words, none of the other civilizations of antiquity, which have otherwise contributed so much to the material and artistic culture of the world, have reached an independent level of scientific thought". He dismisses the Indian use of 28 or 27 Nakṣatra as 'the result of crude qualitative descriptions'*. After ON had pronounced that Indic models were crude, most authors in the History of mathematics repeats this adjective ad nauseum, presumably never having looked at the sources himself.

He does not explain further what he means by a crude qualitative description and neither does he explicate on why he thinks it is fair to say that all astronomical knowledge emanated from Babylon or Greece, even when the relative chronologies do not support such a facile conclusion. To this day, I have yet to find a logical explanation for this strongly held belief by ON. He continues "*while the Nakṣatras were known in India since the first millennium BCE, the contact with modern astronomy dates only after the Roman imperial period. That the preceding Greek occupation of the Punjab (he presumably means the attempted occupation) should have brought astronomical knowledge to India is not very likely, simply because the Greeks themselves seem not to have had any knowledge of mathematical astronomy*" We are relieved that he does not take the viewpoint oft expressed by David Pingree that astronomy arrived in India in the aftermath of Alexander's invasion. But the Sūrya Siddhānta (dating approximately to the 5th century BCE was already available by then and the use of epicycles to represent the fact that the orbit of the sun was eccentric, was known before the advent of Hipparchus and Ptolemy. ON then goes on to say "So *much however can be considered certain, namely that the first and*

lasting impact of Western astronomy in India via Greek astrological texts, operating with Babylonian arithmetical methods. These methods were well known in Alexandria at least at the beginning of our era (1 CE) is attested through Greek and demotic papyri".

But he finally admits "In spite of the pioneering work done by HT Colebrooke (1765 -1837) and G Thibaut (1849 – 1914) and others the study of Hindu astronomy is still at its beginning, the mass of uninvestigated manuscript material in India as well as in Western collections is enormous. May it suffice to remark that many hundreds of planetary tables are easily accessible in American libraries. So far only a preliminary study has been made revealing a great number of parameters for lunar and planetary tables". At least ON had the humility to admit that there was much that we have to learn about Hindu astronomy, In which case he should not have made the statement that he made namely that all fundamental concepts and methods of ancient astronomy for the better or the worse can be traced back to Babylon and Greece., a statement for which he did not have an iota of proof.

The Sanskrit word for Astronomy is **Nakṣatra Vidya**, the Science of the Stars. It is subsumed under a more general field of study called **Jyotiṣa**, which included prediction of future dates of seasons and atmospheric phenomena. There was always a supernatural aspect to the motion of the heavenly bodies and in time the effort to relate these to the positions of the planets evolved into a part of Jyotiṣa that we call astrology. We will not deal with what is known as Astrology in this book (primarily because I am not well versed in the topic), but restrict ourselves to the Astronomical aspects of Jyotiṣa and in particular the positional astronomy of the solar system. In addition, in the ancient Indic system, Uranus and Neptune were not observable by the naked eye and hence we will not discuss these planets.

The primary foci of Indian astronomy are;

- Calculation of the longitudes of the planets
- Computation of the Elements of the Hindu calendar (the Panchānga)
- Determination of direction, place, and time.
- Calculation and Projection of Eclipses of the Moon and the Sun
- Problems connected with the Moon, such as the heliacal rising and setting of the Moon, the phases of the Moon, the elevation of the lunar horns, and the daily rising of the Moon.
- Problems connected with the planets, such as the heliacal rising of the planets, the conjunction of two planets, and the conjunction of the planet with a star.

In the last few years some motivated researchers such as Professor R. Nārāyaṇa Iyengar and Prof Subhash Kak, among others have been taking a close look at the Vedic period, to see if it would yield nuggets of information regarding the extent of the computational astronomy during the Vedic, Post Vedic and Pre-siddhāntic eras. Iyengar has a particularly interesting discussion on Vṛddha Garga[103].

PERIODIZATION

[103] Iyengar, RN Comets and meteoritic showers in the Rigveda and their importance-IJHS-March2010

In examining the various periods we shall look for signs that there was a scientific temper to underpin the inferences that the ancients made, since that would herald the beginning of Astronomy as a science. While we believe meticulous observation is essential to collect the data to make inferences, without intellectual follow up, the subject will wither away and die, due to general lack of interest. An example of such a scientific temper is the determination by Sage Yājnalvalkya that there was a 95 year synchronism between the periodicities of the moon and the Sun. At the end of the 95 year cycle, the phases of the moon will align themselves in relation of the seasons in exactly the same manner. It requires logical thinking, an ability to abstract the essence of the problem, an ability to keep the model simple and no simpler.

Anquetil du Perron	Sudhakar Dvivedi	Subhash Kak
William Jones	Otto Neugebauer	David Frawley*
Thomas Henry Colebrook*	David Pingree	Narahari Achar
Hallstead Thibaut	Sheldon Pollock	R N Iyengar
William Brenand*	Kim Plofker	K D Abhyankar
John Bentley	Bhao Dhaji	Yukio Ohashi
Albrecht Weber	Hegel	Gautam Sidharth
Jean Filliozat*	Rajesh Kochhar	K Ramasubramanian
Pierre Sylvain Filliozat	Ebenezer Burgess	Sreeramula Rajeswara Sarma
Van der Waerden	Jean Sylvain Bailly*	K V Sarma
Fritz Staal	Roger Billard	Michio Yano
Abraham Seidenberg*	AlBiruni*	Srinivas M D
G R Kaye	Said Al Andalusi*	Christopher Minkowski
John Playfair*	Hipparchus	Agathe Keller
Herman Jacobi*	Aristarchus	Setsuro Ikeyama
Claudius Ptolemy	Victor Katz	Takao Hayashi*
William Dwight Whitney	Bal Gangadhar Tilak	Emmeline Plunkett*

FIGURE 1 COMMENTATORS, HISTORIANS OF ASTRONOMY THROUGH THE AGES PRIMARILY FROM THE PERSPECTIVE OF A TRADITION OTHER THAN THAT OF INDIA BUT THE LIST INCLUDES THOSE OF INDIC ORIGIN ALSO.

SOME YARDSTICKS TO GAGE INDIA´S ANCIENT INTELLECTUAL TRADITION

What do we mean when we say we are looking for a scientific temper?

- Is there a systematic approach?
- Is it supported by Empirical Observation?
- Is there an efficient taxonomy
- Are the principles generalized to apply to a wide range of phenomena?
- Does the episteme stand the test of logical rigor?
- Is it confirmed by alternative approaches?
- Can it be verified by repeated experiment?

- Is there emphasis on complete specification of assumptions and hypothesis?
- Are the measures unambiguous?
- Will ancient Indian wisdom satisfy these parameters?
- Does it satisfy the tenets of the Vedic episteme – Prāmanya?
- Is there an ability to translate reason, logic and inference into a series of computational steps to arrive at a quantitatively accurate result?

And last but not least the chronology of the effort is obviously important since the Occidental has taken a proprietary interest in claiming all developments in the ancient world emanated primarily in Babylon and Greece.

We have adopted the following periodization

- The Vedic Era (can be subdivided into, Punarvasu, Mrigaśīrṣā, Rohiṇi) Observational Astronomy, use of Gaṇita (Arithmetic) to design Calendars, use of intercalation, and the initiation of Luni-Solar Calendars.
- The Vedānga Era (Krittika) evolution of ever longer aeons or Yugas, the beginnings of computational astronomy.
- Jaina and Siddhāntic Era (Bharani) The duration of a Yuga and kalpa crystallize
- Islamic Era Aśvini, (Revati)
- The Colonial Era of (Uttara Bhādrapadā)
- Republican Era, the Uttara Bhādrapadā era continues

THE VEDIC ERA (7000 BCE TO 3000 BCE) PUNARVASU TO MRIGA ŚĪRṢĀ ERAS

The final stage 4000 BCE of this era can be called **The Mriga Śīrṣā era** (this is how Tilak refers to the various periods in history) since it is contemporaneous with the VE occurring in Mriga Śīrṣā. Key event is the battle of the Ten Kings (the Dasarajna battle).We hardly know anything about this era.

Key Paradigm The composition of the Vedic literature and the development of the main features of the Indic calendar. What were the main features? The main feature was the reliance of the calendar, merely on naked eye observations of the motion of the Moon and the Sun. The Vedic's embarked on assembling a vast observational data base from which they could deduce the periodicities of the various heavenly bodies; the goal being to devise clocks corresponding to the periodicity of the particular planet. By the end of this period the key features of the Indian calendar were in place. During the Vedic period, there was perhaps a realization that no single calendar would be able to accommodate the various needs of society. We shall refer to this era as the Vedic era in the context of the development of Astronomy. The Vedic literature is the oldest extant literature of the human species and dating it carefully and accurately is one of the most important endeavours of a historian. It certainly deserves a more careful look than the cursory and shabby treatment given to it by Freidrich Maximilian Müller and which has now been cast in stone never to be challenged by lesser mortals.

There is evidence that Indian deities wound their way into Greek mythology. That this is the case is quite clear from the similarity of Zeus and Dyaus, Jupiter and Dyaus Pitr or **Bṛhaspati** बृहस्पति. This needs an entire book to expound on and it would take us too far from the main topic of this book. The reader is

referred to Pockocke[104] and Kak[105] as a starting point. Similarly Kak[106] explores the connections between Babylon and India, to explore possible transmissions in either direction.

By the end of the Vedic era the planets have been identified, although it appears there is no single place in the texts where they are mentioned altogether. The list below has been compiled by Kak[107]

Mercury Buddha, Saumya, Rauhineya, Tonga
Venus Ushanas, Sukra, Kavi, Bhrigu
Mars Angaraka, Skanda, Mangala
Jupiter, Dyaus Pitr, Zeus (Dyaus), Brihaspati, Guru, Angirasa
Saturn Sanaischara, Sauri, Manda, Pangu, Palangi

THE VEDĀŃGA ERA (3000 BCE 800 BCE)

Comprises the **ROHIṆI ERA** and the **KRITTIKA ERA**
Key event is the development of Darśanas, Brāhmaṇas, Vedāńgas (Logic, Grammar, epistemology, mathematical computation, Astronomy, development of numerical symbols and the place value system. This was indeed the most fertile period of the ancient era, where there are clear signs of computational prowess. It is in this period that the ancient Indic displays his remarkable talents in developing algorithms for computation. It is also the age when Indic sciences made tremendous advances and India was regarded as the leading nation in many fields including astronomy

Key paradigm - The principles of epistemology lead to the Perennial Philosophy and an all-encompassing world view. This period includes the Brāhmaṇa era, the Sūtra era, and the Upanishad era. We shall call this the Vedāńga Jyotish or Vedāńga Era, remembering that the Vedāńgas were a prerequisite for studying the Veda.

THE JAINA AND SIDDHĀNTIC ERA (1000 BCE – 1000 CE) OR THE BHARANI/AŚVINI ERA

Key event: Unravelling the Science behind Computational astronomy
Contrary to descriptions in Occidental versions of Indology, there was continuity in the tradition up to 18xx CE culminating in the work of Chandraśekhara Sāmanta. It is this extraordinary continuity in the tradition that the Occidental has been envious of and has tried his best to chip away at both the antiquity and the content

THE ERA OF CONFLICTING PARADIGMS (1000 CE TO 17TH CENTURY) – THE ERA OF DENIAL

This era is contemporaneous with VE in Revati (η Piscium)
Key event: Islam asserts its presence in the Indian Subcontinent

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[104] *Pococke,E, http://www.amazon.com/India-Greece-Containing-Colonisation-Propaganda/dp/B002IVUYUK/ref =sr_1_2?ie=UTF8&s=books&qid=1275771639&sr=1-2, India in Greece …*
[105] *Kak, S C, 2005a, "Greek and Indian cosmology: review of early history." In The Golden Chain. G.C. Pande (ed.). CSC, New Delhi, 2005; ArXiv: physics/0303001.*
[106] *Kak, 2005b*
[107] *Kak, 1996a (see appendix H for complete listing)*

Key paradigm: Hindu Life is cheap and Hindu freedom is even cheaper. Vast proportions of the population were killed or sold into slavery, as a result of which the economics of slavery becomes unsustainable. For the first time in millennia, the Indian population took a dip in the 15th century.

There was accompanying disruption due to frequent wars and progress was sporadic in Astronomy and Mathematics during the 13th and 14th centuries. The Buddhist monasteries and Universities at Nalanda, Odantipura, and Vikramshila were completely destroyed and Delhi became a ghost town after the pillage of Tamer Lang in 1373 CE By the time of the 15th century, the canter of gravity of the study of astronomy had shifted to the southern part of the subcontinent. But there was significant interchange with Damascus and Baghdad just prior to the assumption of Islamic rule in India and as a result the Indian tradition was kept alive both within the confines of the subcontinent as well as in Central Asia .But by that time, Islamic rule was established in India, Damascus and Baghdad were looted and destroyed by Hulagu the Mongol, and the Golden period of the Khilafat , where the Mutazili reform, which had a brief but influential sojourn, and presumably had the backing of the Khalīf, was over and shortly thereafter the Reconquista completed the ouster of Moors from Spain. The Mughal Empire based in Delhi and Agra became one of the Canters of Islamic culture, just as Cordoba was the Center for 600 years prior. One of the technological innovations was the production of a seamless globe, during the Moghal era. The Indic savant was employed by the Muslim sultans and the tradition was very much alive with many commentaries and original texts during this period. But the overall impact of the period was negative, and except for the deep south in Kerala, and there was not much innovation in the area of observational astronomy. Just as Europe was embarking on a journey towards Renaissance, the Indian subcontinent underwent massive disruption due to wars starting from Nadir Shahs loot of Delhi in the 1730's that did not stop till the Great Indian Uprising of 1857 resulting in the Anglo Indian War shortly thereafter. While the steady regeneration of ideas continued on, the loss of patronage from rulers resulted in the drying up of the well and eventually by the 18th century, the infusion of fresh blood and ideas ceased with few exceptions, with the last of the Kerala School of Astronomers.

THE INDIC REBIRTH (19TH CENTURY TO PRESENT) AND THE AGE OF COLONIZATION (UTTARA BHĀDRAPADĀ, उत्तरभाद्रपदा)

The Policies of the Colonial State and the Indian Response

Key Event - The Impoverishment and Malnourishment of India. The Indic tradition hangs on by a thread, after the assault by Macaulay Never let it be said that the British were awed by the responsibility of ruling a vast subcontinent. They went about the myriad tasks of undermining the Hindu's belief in his own tradition in a very thorough and satisfactory manner while at the same time impoverishing the country. In fact the British experience in India should serve as a text book or manual on how to run an empire with an Iron hand with as few as 30,000 people (in a land of 250 million) at any given time, and in the process make them believe they achieved independence nonviolently even though 50 million Indian may have died in the 50 odd famines that took place during their rule.

All pretense at treating the Indic as an equal or being objective about Indic accomplishments was thrown out along with the bathwater, after the unsuccessful Anglo Indian War of 1857[108],[109] as the British exacted a massive retributive Pogrom of immense proportions in the Gangetic valley with a barbarism and bestiality that has rarely been equaled in the history of humankind. Later in the 20th Century, the great British Leader and historian Sir Winston Churchill, is reported to have accused the Indic on more than one occasion of being a bestial people. The scion of the House of Marlborough should have been well aware of what the bestiality of his own countrymen accomplished in India. The consequence of all this was that a significant section of the Indic population no longer regarded the British as an impartial purveyor of Ancient Indic Traditions, assuming they did at one point. The Colonial power came to be viewed increasingly as a predator whose avarice knew no limits.

The Occident views the net impact of the Indic Philosophia Perennis as a negative that causes the Indic to become resigned to a less attractive outcome without putting up a fight without at the same time considering the extent of the human carnage that took place, the major brunt of which was borne by the intellectual leadership. Generally the British have soft-pedaled the butchery that went on during the 6 centuries in which Islamic rulers dominated the Indian subcontinent. But there is very little soft-pedaling you can do if the Muslim historians themselves are bragging about the 100,000 skulls they piled up in a single day and the thoroughness with which they sought to eliminate the Brāhmaṇa from Indian society. But in the end it dawned upon the Islamic rulers, after many centuries of trying, that killing every single Hindu in the subcontinent was not a practical proposition. Jehangir admitted as much when he said there are just too many to kill. In other words it was the stupendousness of the task that daunted them and not the morality of killing huge numbers of people. Read for yourself and make up your own mind[110].

This digression into the absolute debasement of the average Indic is relevant to explain the lack of progress in the sciences during much of the Nineteenth century. The Occidental rarely expresses remorse or takes responsibility for the many egregious acts that led to the massive famines that bedevilled India[111] during the ensuing 150 years, preferring to lay the blame for the widespread poverty of India on the hapless Brāhmaṇa who had neither the power nor the weaponry to enforce his will on others. It was a time tested technique of belittling the intellectual leadership of a country while systematically dismantling the ancient traditions of India and doing their best to fan the fissures in Indic society so that they could prolong their authoritarian rule over the subcontinent in the process. The tale of how a small Island nation subjugated and then subsequently ruled over hundreds of millions of people, with an ancient tradition, in a distant land is not totally unrelated to our own story of the nature

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[108] *Tope, Parag, Operation Red Lotus, Rupa and Co., Delhi*

[109] *Verma, S. P, Eighteen Fifty Seven, Aryan Books International, 2007, Delhi.*

[110] *H. M. Elliot (ed. J. Dowson), "The history of India by its own historians; the Muhammadan period" (8 vol. London 1867).*

[111] *There is suspicion that the famines were triggered deliberately by exporting all the food that was available, with a view to depopulate the continent of its original inhabitants but like Jehangir, they found there were too many of them. But the colonial overlord was far more successful in impoverishing India and altering the mindset of the Indic than he had probably anticipated.*

of colonial forms of knowledge as Bernard Cohn describes it very aptly in his book[112]. The general approach was to trash everything Indic and ridicule the antiquity of the Indic tradition. This is not to say that there were no Englishmen who were dedicated to the principles of equality, liberty and justice. The few that were honest and had a conscience were overwhelmed by the vast sea of unimaginative individuals who could not break away from the colonial precepts that rationalized their presence in India as rulers. They certainly did not need much convincing, surrounded as they were by a plethora of servants, a lifestyle they could hardly emulate in cold and dreary England. We call it the era of the Colonial Paradigm, where the Indic reverted back to the bottom of the Maslow Hierarchy in the relatively short period of time between 1770 and 1857 and was compelled to turn his energies merely to survive. So thorough was the looting of India that within the short time period of 70 years the transformation of India to an illiterate state with a malnourished populace was complete. During this period the theft of intellectual property was also stepped up at an accelerated pace.

Key Paradigm - The reductionist portrayal by the Occident of the Indic in very unflattering terms. It is perhaps not an exaggeration to say that the net impact of the Colonial Paradigm, was a massive plummeting of the image of the Indic and his civilization and the denial of an Indic antiquity became the new reality.

THE MODERN REPUBLIC AND THE OCCIDENTALIST CARICATURE OF THE INDIC (1947 TO PRESENT)

- Key event – Independence is not accompanied by independence of thought
- Key Paradigm - The Globalized Indic Diaspora

Indian Astronomy, despite what one may read in Occidental narratives, has a long, continuous, and unbroken history of evolution. In fact I would go so far as to aver that it is one of the longest unbroken traditions that are still alive. This is in fact one of the points of contention between India and the Occident when the Occidental maintains, in spite of this glaring contradiction that India has no tradition in Astronomy. In every other instance, the Occident has taken a commanding position as the spokesman for the various extinct civilizations, with nobody to challenge them, because there was no representative alive from the civilization to question their scholarship. This was the case with the Egyptian Pharonic civilization, as well as others such as the Meso American and the Babylonian civilizations. He naturally assumed that such would be the case with the Indic civilization. To the chagrin of the Occidental, that has not happened and the modern Indic has decided to challenge many of the conclusions of the Occidental, particularly those which were especially egregious and self-serving. In this he had no choice in the matter, because the publications in the Indic world are simply ignored, as being of no consequence. The occidental has not taken kindly to this assertiveness on the part of the modern Indic's and he has been less than thrilled by the expression of a contrary opinion. Not only was the modern Indic ungrateful for the attention that his civilization was bestowed but he actually had the temerity to question the conclusions of the Occidental. The general reaction of the Occidental has been one of consternation and ridicule. But it was very rare that the occidental would have the courage to challenge him on the merits of the argument. Truth to tell, even the more sympathetic amongst the

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[112] Cohn, Bernard "Colonialism and its forms of knowledge". In a very perceptive set of articles, Cohn describes how the colonial power coerced the Indic to abandon his traditional sources of knowledge, while at the same time he was perusing the ancient books with vigour and tenacity. See Figure 3 in Prologue.

Occidental Observers of India, such as for instance Koenraad Elst, could not bring himself to admit that India had a historical tradition when he asserted in a communication, that we consider being grossly in error.

"It seems that you mean that the question of rewriting history does not arise because what Mills, Marx etc. wrote is no history at all, and the chronology of India as presented at the chronology is merely a restoration of an existing history of India that the colonialists and Marxists have wiped under the carpet. ***I'm afraid that, on the contrary, no pre-colonial native chronology of India existed, only bits and pieces from which we now, taught by the colonials in historical methods, may hope to compose a consistent chronology."***

In fact precisely the opposite happened, the British selected bits and pieces out of the all-encompassing Purāṇic texts, despite several caveats from Pargiter that there was no evidence to show that the dynastic lists were ever falsified and could not be ignored simply because of a whim. They also ignored large parts of Indian History such as the Āndhra Sātavāhanas, the Vijayanagar Empire, the history of the south etc and adopted a priori the Hegelian hypothesis that the history of India was a history of invasions and that nothing worthwhile originated in India, without examining the facts. The tended to down play any historical fact that challenged their version, that the Āryans brought the Vedic civilization into India and were to be regarded as the first of many invaders and that India had no native civilization to speak of.

We quote Tilak in Orion, page 16-17 of his book.

"Prof Weber and Dr. Schrader, appear to doubt the conclusion (that the Vedics knew how to reconcile the Lunar with the Solar year, on the sole ground that we cannot suppose the primitive Āryans to have advanced in civilization as to correctly comprehend such problems".

To which Tilak caustically observes *"This means that we must refuse to draw legitimate inferences from plain facts, when such inferences conflict with our preconceived notions about the primitive Asian civilization. I am not disposed to follow this method, nor do I think that people who knew and worked with metals, made clothing of wool, constructed boats, built houses, and chariots, performed sacrifices, and had made some advances in agriculture were incapable of ascertaining the Solar and the Lunar year."* Clearly, Tilak recognized that there was a version of the 'loin cloth syndrome" at work here, whereby the Occidental often gages the extent of the civilization and the general competency of a people, by the number of layers of clothing he wears. This is a consequence of the colder climate that he hails from.

As we shall see in Chapter VI on Astro-chronology, Tilak was a pioneer in the use of astronomical observations to determine the date of a particular event. However, he did not have the confirmation of the drying up of the Sarasvati River to put the pieces of the puzzle together as we have now been able to do.

We shall call the present period, the era of Discovery and Synthesis. Rarely in History, do such a large group of people get a second chance. The Indics have gotten a second chance to show that the ancient wisdom and the prodigious output, that resulted, was not a flash in the pan, but an artifact resulting

from a well laid out epistemic root system coupled with a deep and abiding curiosity to unravel the mysteries of time and the universe. It is too early to say whether the Indics will grab this opportunity and run with it or settle for an also ran status. The initial choices they made where they discarded the sidereal data for the year and elected to fall in step with the clumsiest calendar of them all, the Gregorian, indicates a loss of nerve, perhaps engendered by long years of servility to barbarian invaders. We do not wish to go into the details of why this may have been a suboptimal choice, but the reader can get enlightened on the issues in the chapter on 'Time Latitude, Longitude, and the size of the globe' CK Raju's CFM, p.201, and especially the section on the Calendar and Indian agriculture.

THE VEDIC ERA

We will consider the end of this period to be synonymous with the end of the period when the Vedas were composed. While there is no qualitative reason to differentiate between the Saṃhitā period and the Vedāńga period, that includes the Sūtra period other than the fact that developments accelerated during the later periods. The progress has been continuous and steady. We do not know when codified and standardized scripts appeared, but we find it difficult to visualize a situation where no attempt was made to illustrate an idea on a medium until such a codification took place. The development of a script is also an evolutionary process just as language evolves. We emphasize this since it seems very likely that symbolic manipulations may have preceded a standardized written script for language. Again we find it hard to visualize an individual being able to develop the relatively complex algebra needed for astronomical calculations, without the ability to manipulate symbols in algebra, just as it is equally difficult for *Pāṇini* to have composed the *Ashtādhyāyi*, without a script. There are hints of the ability to do just that (symbolic manipulation) in the Vedic era. Subhash Kak, who has written a plethora of papers on the topic, has summarized the state of astronomy during the Vedic era in a chapter titled Astronomy and its Role in Vedic Culture in a recent book[113]. The other papers that are relevant to this narrative from his extensive portfolio of publications include those in this endnote. The others who have studied this topic carefully include BG Siddharth, David Frawley. It is apropos to realize that already in the Vedic age there are references to the decimal place value system. See for example Bhu Dev Sharma[114]. The paper presents the following points:

1. The numbers 1, 2, 3 ... 9, with 9 as the largest single digit find mention in the Suktas and Mantras of the Vedas;
2. There is enough evidence that a method to denote 'zero' was known to Vedic seers.
3. The Vedas refer to what in the modern terminology are called 'sequences of numbers';
4. That the idea of fractions, both unit and others, has also found clear mention in Vedas.

It is this facility with numbers, which was a hallmark of the Indic effort, that enabled the ancient Indic to make sense of the observational data that he collected, and the cycles that he postulated based on the orbital periods of the planet, using a least common multiple as the shortest of such cycles

ASTRONOMY IN THE ANCIENT ERA

[113] Pande, G. C. "The Dawn of Indian civilization" Project of History of Indian science, Philosophy and Culture, Centre for the study of civilizations,1999
[114] Bhu Dev Sharma 'Origin of Mathematics in the Vedas' , Paper presented at the ICIH 2009, Jan. 9- 11, 2009

There is no central repository or index that we can refer to, in order to study the corpus of astronomical knowledge in the Vedas. The effort of gleaning the knowledge from the Veda remains a painstaking one of cataloging all the occurrences of Astronomical nature that occur in the Saṃhitā, so there is every likelihood that we may be only aware of a subset of statements relative to astronomical phenomena and may not be able to exhaust all of the potential occurrences. This state of affairs where the knowledge contained in the Veda is slowly but surely getting lost with each succeeding generation has lately accelerated due to the adoption of English as the medium of instruction and as a result of the fact that few are willing to spend the arduous effort needed to master the Sanskrit language and the contents of the numerous vedic texts that are contained in the corpus of the Vedic literature. (See Appendix D Vedic epistemology). The Census of the Exact Sciences in Sanskrit in 5 Volumes is a monumental piece of work by David Pingree , and is extremely useful for such a purpose. We will classify these statements depending on the subject, into some of the categories that we have discussed in Chapter I.

Astronomy was recognized as a discipline of scholarly study by the Vedics. The Yajurveda Saṃhitā mentions Nakṣatra Darśaka (Stargazer) and ganaka (Calculator) as professions that were needed by the society[115] . In the Chandogya Upanishad, mention is made of Nakṣatra Vidya or science of the Stars. Atharva Saṃhitā contains the complete list of 27 Nakṣatras. By this time the status of this discipline, coupled with the complexity of its content, made it a branch of knowledge worthy of the study of the Brāhmaṇa, traditionally the class of people endowed with the *Guṇa* (गुण) necessary for intellectual effort and Jyotiṣa became a part of the Vedāńga . The Hindu marriage includes an obligatory effort to point to Dhruva, the pole star, indicative of the constancy that the spouses pledge to each other.

HOW DO YOU DESIGN A CALENDAR ESPECIALLY IF YOU WERE IN THE 4TH OR 5TH MILLENNIUM BCE?

A calendar is a system of organizing various units of time, which can be verified periodically from natural phenomena for the purpose of reckoning time over an extended period. The natural units of time are the day, the month, and the year. They are based on the Earth's diurnal rotation on its axis, the Moon's revolution around the Earth and the Earth's revolution around the Sun respectively and are by far the most easily observable of various natural phenomena which exhibit the property of periodicity. We will elaborate on the historical evolution of the calendar in the next chapter, but we will lay the groundwork by defining various measures of time, which can be easily quantified based on the observation of the Sun and the Moon. After all the smoke and dust has cleared away, there are 3 Basic Types of Calendars in use today. From time memorial the Indics have had both a solar and a lunisolar calendar.

A Solar calendar, of which the Gregorian calendar in its civil usage is an example, is designed to maintain synchrony with the tropical year. Days are intercalated (forming leap years) to increase the average length of the calendar year, in order to synchronize with the tropical year and hence the seasons. A

[115] Incidentally , It might be of passing interest to mention that in one of my first career assignments at Siemens Schuckertwerke, in Germany, I was called a Berechnungs Ingeneur – apparently some titles do not change even over long periods of time and multiple geographies.

Solar calendar year can be divided into months but these months ignore the Moon. The Gregorian calendar is a Solar calendar with a common year having 365^d and a leap year having 366^d. Every fourth year is a leap year unless it is a century year not divisible by 400. The Indian National Calendar initiated by the Calendar Reform Committee of 1957, is basically a Solar Calendar.

A Lunar calendar, such as the Islamic calendar, follows the Lunar phase cycle without regard for the tropical year. Thus the months of the Islamic calendar systematically shift with respect to the months of the Gregorian calendar. A Lunar calendar consists of a number of Lunar months with each month covering the period between two successive new Moons or full Moons. We say that the resulting Lunar month follows, or depends on, the Lunar cycle. Each calendar or Lunar year has 12 Lunar months. Each month has an average length of about **29.5^d** . This amounts to about 12 x 29.5 = 354^d a year, around 11^d shorter than the tropical year. Hence a Lunar calendar ignores the tropical year and does not keep in line with the seasons. The Islamic calendar is a Lunar calendar.

The Luni-solar calendar has a sequence of months based on the Lunar phase cycle; but every few years a whole month is intercalated to bring the calendar back in phase with the tropical year. The Indian Panchānga, Hebrew, Chinese calendars are examples of this type of calendar. A *lunisolar calendar* is designed to keep in phase with the tropical year using Lunar months. A whole Lunar month is occasionally added at every few years interval to help the calendar keep up with the tropical year. This additional month is known as the *leap month* or the *intercalary month or an embolism*. The Chinese calendar is a lunisolar calendar, consisting of 12 Lunar months, each beginning at new Moon. A normal calendar year has 12 months and a 13th month is added according to certain rules to synchronize with the tropical year. In the subsequent sections, we will see that the Indian Religious Calendar or the Panchāngam is a lunisolar calendar and is made to approximate the sidereal year instead of the tropical year. The sidereal year is the more appropriate measure of the two, especially for the day when we are capable of Galactic travel.

ARITHMETICAL AND ASTRONOMICAL CALENDARS

There is another different way of grouping calendars. We can classify calendars that are operated by straightforward numerical rules as **arithmetical calendars**. The Metonic calendar which intercalates leap months at predetermined intervals is an arithmetical calendar. So is the Gregorian calendar that is in universal use today. A normal year has 365^d and a leap year having 366^d. Every fourth year is a leap year unless it is a century year not divisible by 400. Furthermore, the lengths of months in the calendar are fixed with February having 28 days in normal year and 29^d in a leap year. We see that there is an arithmetical formula to determine which year is leap. Together with lengths of months being fixed, we can easily and accurately construct the Gregorian calendar for any year in the future without recourse to astronomical data. Calendars that are mainly regulated by astronomical events are **astronomical calendars and have the capability to self-correct, based on astronomical data.** These calendars do have some arithmetical components. However, they are really close approximations to their related astronomical events. The Indian Solar and Lunisolar calendars are astronomical calendars. By such a criterion, the Indic lunisolar calendar is by far one of the most sophisticated calendars of all time. The intercalation is done using astronomical values and not by a predetermined arithmetical rule, such as in

the Metonic cycle. Lengths of the calendar year and Solar months in the Indian Solar calendar are likewise determined by the time taken for the Sun to travel along certain paths along the ecliptic. The process of rounding the lengths to whole numbers depends on a set of rules involving the occurrences of some astronomical events. Since the times of astronomical events vary from year to year, lengths of the calendar year and Solar months also vary. Hence we cannot formulate any Arithmetical rules to determine their lengths. We will discuss the Indian Solar calendars in greater details later.

HISTORY OF THE INDIAN CALENDAR

Like most Asian calendars, traditional Indian calendars did not employ the Solar year and day (i. e. tropical year and Solar day) but the Sidereal year, the Synodic month (**29.5306^{d}**) and the Tithi. It remains to be said that all three calendar types namely the Solar, Lunar and Luni solar are in widespread use today in the subcontinent. Thus, the calendrical year based on the sidereal year is defined as the time between two successive passes of the Sun through a certain star's circle of declination. Lunar days and sidereal months are also used, and in certain lunisolar calendars Lunar year and Lunar month are taken into account, too.

The Astronomical knowledge or the theory behind the observations of Ancient India was eventually codified in scientific treatises, called Siddhāntas. In them, values for the lengths of months and years were given representing the latest knowledge at the time the Siddhānta was written. The values range from **365.258681^{d}** in the Āryabhaţīya to **365.258756^{d}** in the Sūrya Siddhānta and are all too long compared with the modern sidereal year length of **365.25636^{d}**. Still for their time they were remarkable in their precision.

The history of calendars in India is a remarkably complex subject owing to the continuity of the Indian civilization, the diversity of cultural influences, and the vast range of climatic diversity that the Indian subcontinent encompasses. In the mid-1950s, when the Calendar Reform Committee[116] made its survey, there were about 30 calendars in use for setting religious festivals for Hindus, Buddhists, and Jainas. Some of these were also used for civil dating. These calendars were based on common principles, though they had local characteristics determined by long-established customs and the astronomical practices of local calendar makers. In addition, Muslims in India used the Islamic calendar, and the Indian government used the Gregorian calendar for administrative purposes. There are 4 basic calendrical types in use today in the subcontinent

a. Lunar, b. Solar, c. Luni-solar and d. **Diurnal** – this is simply a day count or the Ahargana which was later adopted by Josephus Justus Scaliger as the Julian Day count in Europe in 1600 albeit with a different starting epoch. It was common to find in many countries of antiquity, the simultaneous use of more than one calendar system, one Solar for recognition of seasons, and one that was far more elaborate and was used to determine the accurate moment to perform Yagna's or offerings to the Deities. Early allusions to a lunisolar calendar with intercalated months are found in the hymns from the RV, dating from the second millennium BCE Literature from 1300 BCE to CE 300, provides information of a more specific nature. A five-year lunisolar calendar coordinated Solar years with synodic and sidereal

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[116] *Saha MN, "India's Calendar Confusions" Journal of the Royal Astronomical Society of Canada, Volume XLVII, no.3, May-June 1953, pp 977-105*

Lunar months. This date refers to the likhita parampara or the scriptural tradition. The oral or Srautic tradition dates much farther back as we shall see in chapter IV.

It is the opinion of Occidentals that Indian astronomy underwent a grafting of new ideas in the first few centuries CE. As advances in Babylonian and Greek astronomy became known, although the basic structure of Hindu Astronomy and the reliance on the Nakṣatras as the principal means of identifying the events depicted in the celestial clock remained invariant. However, we remain deeply skeptical of such sentiments, based as they are purely on conjecture and the wishful thinking that accompanied the deeply held belief that Indians could not possibly have made such advances. We do not preclude interchange of ideas, but again there is zero evidence of a clearly recognized Greek or Babylonian text having been translated into Sanskrit and we see little hope that the occidental will find any new texts in Greek that would serve as a text that the Indics borrowed from.

Our current verdict is that given the data that we have today, that one of the major contenders for the earliest origins of Astronomy remains the Vedic era Astronomy.

YEARS, MONTHS, DAYS AND YUGAS

A key principle in the formulation of the Indic calendar was the notion that all the cycles that were utilized should be observable with the naked eye. The first thing the ancients observed was that the Sun and the Moon moved along a certain fixed path in the skies with a certain cyclical regularity. They called this path the क्रांतिवृत्त Krāntivṛtta or the ecliptic as opposed to the Vishuvat, विशुवत –Celestial Equator. There were certain groups of stars or asterisms that were on the path of the Sun and the Moon that could be used to identify the location of the Sun just before rising. And these were termed the Nakṣatra.

WHAT DID THE VEDICS KNOW AND WHEN DID THEY ESTABLISH THE BASIC FRAMEWORK OF INDIAN CALENDRIC ASTRONOMY

Āśleṣā is read as Asresha
Ardra = Bahu
Tishya = Puṣya
Vichitrasu = Mūla
Srona = Asvatha = Srāvana
Sravishta = Dhanishta (when the transition was made to 27 from 28 Nakṣatras
Prosthapada = Pūrvabhādrapadā and Uttarabhādrapadā
Apabharani = Bharani

INDIAN COSMOLOGY AND TIMELINES OF HISTORY

In what follows, we introduce the Indic concept of Time and the cosmological time frames of the Yugas. There are some who feel that the reference to a Mahāyuga going back 4,320,000 years is without foundation, since we do not have recorded history going back that far and the more appropriate measure to us is a time scale that is consonant with the start of river valley civilizations.

The infrastructure of Hindu astronomy is built upon the foundation of their unique concept of Time and cosmology. No other culture on Earth has or is known to have such a unique system of cosmology. The only other culture to come close to the vast scale of time conceived by the Hindus is the Mayan. Western scholars have completely misunderstood the value of the Hindu cosmological time cycles and believed them to be nothing more than crude number speculations.

The RV (IV.58.3) speaks of the cosmic bull with "four horns, three feet, two heads, and seven hands." This has been identified by some as the kalpa number 4,320,000,000, the great age in Vedic astronomy, equal to a Brahma day. The Atharva Veda (VIII.2.21) also mentions yugas of 10,000 years in length, "ten thousand, two yugas, three yugas, four yugas," or a total period of 100,000 years. . This has also been interpreted as 4,320,000 with numbers read from right to left, which is the way we do arithmetical operations

Meanwhile the Yajur Veda (Sukla Yajur Veda XVII.2) relates the universe to the number 1,000,000,000,000, giving names for numbers from one to ten all the way up to this number which is ten to the twelfth power. According to Śatapatha Brāhmaṇa X.4.2.25 all the three Vedas amount to "ten thousand eight hundred eighties (of syllables)" or 864,000, the number of muhurtas (48 minute periods or 1/30 of a day) in eighty years. Such numbers show a use of mathematics on a grand scale to understand the universe in which we live, not only in terms of time but in terms of space. This concern for large numbers is well known in later Indian mathematics and astronomy of the classical.

TABLE 1 A TIMELINE OF EVENTS AND OBSERVATIONS RELEVANT TO ASTRONOMY /CALENDAR Refer to Table 3 (RNET) in chapter VII to obtain the dates for the cardinal points in the orbit. There are many sources for these observations. One of the sources for this compilation is Kandula[117]
Terminus ante quem of 4000 BCE Yajurveda mentions Nakṣatra darshaka (astronomer) and Nakṣatra Vidya (note the qualifications of an astronomer in chapter XI under Varāhamihīra)
Terminus ante quem of 4000 BCE Chāndogya Upanishad mentions Nakṣatra Vidya (CU, 7.2.1, 7.7.1)
Maitreyani Saṃhita ,2.13.20
Kathaka Saṃhita,
Taittiriyā Saṃhita gives list of the presiding deities of the 28 Nakṣatras
Atharva Veda[118] mentions the heliacal Rising of stars. (AV, 2, 8, 1).

[117] *Satya Sarada Kandula http://oldthoughts.wordpress.com/2009/03/12/equinoxes-and-dating-vedas-the-data/*

[118] *The Atharva Veda Saṃhita is the text attributed to the Atharvan and Angirasa poets. It has 760 hymns, and about 160 of the hymns are in common with the RV. Most of the verses are metrical, but some sections are in prose. The terminus ante quem date for the compilation of the AV is estimated to be 1500 BCE, although some of its material may go back to the time of the RV, and some parts of the Atharva-Veda are older than the RV though not in linguistic form.*

The RV mentions the rising of the star Sirius (RV, 1,105.11) – 5000 BCE
The AV enumerates the Nakṣatras (AV, 19, 7, 1-5). The Seer of this Hymn is Gargya, another of the original band of Astronomer Savants of the ancient era, whose hymn AV 19, 8, is also a descriptor of asterisms. The number of the asterisms is (28) also listed in the hymn. The Nakṣatras are listed pretty much with the same names as today in the AV Parisista 1, Nakṣatra Kalpa 1.
The names of the stars in Krittika (Pleiades) are listed in the Taittiriyā Saṃhita (TS, 4.4.5). The TS is part of the Yajurveda
11,413 BCE Taittiriyā Brāhmaṇa 3.1.2 refers to Pūrva Bhādrapadā Nakṣatra*'s* rising due east, a phenomenon occurring at this date (Dr. B.G. Siddharth of the Birla Planetarium, Hyderabad), indicating earliest known dating of the sacred *Veda.*
8948 BCE Taittiriyā Saṃhitā 6.5.3 places Pleiades asterism (Krittika) at winter solstice, suggesting the antiquity of this *Veda.*
7400 BCE, RV10.64.8, Tishya (δ Cancri) is invoked. The Vernal Equinox occurs in Tishya in 7414 BCE
5776 BCE Start of Hindu king's lists according to Greek references that give Hindus 150 kings and a history of 6,400 years before 300 BCE; agrees with next entry.
7300 BCE, RV verses (e.g., 1.117.22, 1.116.12, 1.84.13.5) say winter solstice begins in Aries (according to D. Frawley), giving antiquity of the first mandala of the *Vedas*.
5500 BCE Date of astrological observations associated with ancient events later mentioned in the *Purāṇas* (Alain Danielou).
4000 BCE The oldest astronomical observations ever recorded (Egypt and Central America).
3928 BCE, July 25: the earliest eclipse mentioned in the RV (according to Indian researcher Dr. P.C. Sengupta).
4000 BCE – Origin of Luni Solar Calendar in the Veda
3800 BCE Jacobi[119] and Tilak, independently come up with the same answer for the age of certain mandalas of the Ṛg .Veda. There is an excellent analysis of this period by Narendra Nath Law[120]

The Atharva Veda is preserved in two Recensions, the Paippalāda and Śaunaka. According to Apte it had nine schools (ŝākhā). The Paippalada text, which exists in a Kashmir and an Orissa version, is longer than the Saunaka one; it is only partially printed in its two versions and remains largely untranslated. The vulgate text is dated to 200BCE... Further we have evidence that Paippalada one of the early collators, and Vaidharbih one of the late contributors associated with the Atharvana text lived during the reign of prince Hiranyanabha of the Ikshvaku dynasty. This allows us to state to that the core AV composition was at least complete by 1500 BC. Thus the AV is not particularly recent in the Vedic Saṃhita tradition and falls well within the range of the second phase of Vedic creativity- the classic mantra period that followed the Rgvedic period. Not surprisingly there are some similarities in the Yajur and Atharva collections. "

[119] *Jacobi, Hermann George (1850-1937) was one of the first to suggest that the Vedic Hymns were collected around 4500 BCE based on Astronomical observations made by the Vedics. The chair for Indology and Comparative Linguistics at Bonn University was very distinguished. Founded by August Wilhelm von Schlegel in 1807, Hermann Jacobi was the chair holder from 1889 to 1922. He had a great number of famous disciples, amongst them Helmut von Glasenapp, August Winter and Vasudeva Gokhale. The Russian scholar Cherbatskole, the Italians Ambrosio Balini, Luigi Salvi, and George Herbert Grierson were regularly corresponding with him. It was said that all Indian scholars visiting Europe during the 1920s and 1930s, would pay their respect to Professor Jacobi. But how did Dr. Ambedkar get in touch with Hermann Jacobi? In 1913/ 1914 when Hermann Jacobi was visiting professor at*

3500 BCE to 4000 BCE Taittiriyā Saṃhitā and Kṛṣṇa *Yajurveda* 4th *Kānda* 4th *Prashna* of Andhra School provide a list of 27/28 Nakṣatras
3300 BCE Parasara compiles the first text on Astronomy
3200 BCE In India, a special guild of Hindu astronomers *(Nakṣatra darshakas)* record in Vedic texts citations of full and new Moon at winter and summer solstices and spring and fall equinoxes with reference to 27(initially 28) fixed stars *(Nakṣatras)* spaced nearly equally on the Moon 's ecliptic (visual path across the sky). The precession of the equinoxes (caused by the mutation of the Earth's axis of rotation) makes the Nakṣatras appear to drift at a constant rate along a predictable course over a 25,800-year cycle. Such observations enable specialists to calculate backwards to determine the date the indicated position of Moon, Sun and Nakṣatra occurred.
3100 BCE Reference to vernal equinox in Rohiṇi (middle of Taurus) from some Brāhmaṇas, as noted by B.G. Tilak, Indian scholar and patriot. Now preferred date of *MBH* war and life of Lord Kṛṣṇa
3000 BCE – Yājnavalkya propounds the 95 year period for the synchronization of the Solar and Lunar cycles with a resulting error of .0012 %
3000 BCE The first written materials on astronomy (Egypt, China, Mesopotamia and Central America)
2697 BCE The oldest preserved record of a Solar eclipse (China)
2285 BCE Sage Gargya (born 2285 BCE), 50th in Purāṇic list of kings and sages, son of Garga, initiates method of reckoning successive centuries in relation to a Nakṣatra list he records in the *Atharva Veda* with Krittika as the first star. Equinox occurs at Kārtika Pūrnima. A complete Nakṣatra (Constellation) list is in ubiquitous use by this date
2221 BCE Reference to vernal equinox in Krittika (Pleiades or early Taurus) from *Yajur* and *Atharva Veda* hymns and *Brāhmaṇas.* □□□ □ □□ □□□□□□□□□□ □□□□□□□□□ □□□□ □ □□□□□□□□□□□□**,** *The Kṛttika do not deflect from the East. This means that the Pleiades were observed to rise always at the east. This is only possible when the first point of Aries was on the constellation Pleiades.* This corresponds to Harappan seals that show seven women (the Krittika) tending a fire. (Tilak, Siddharth, Narahari Achar). Probable date for composition of the Atharva Veda.

*Calcutta University, Dr. Ambedkar just left for the US to take up his studies at Columbia University. The contact must have been forged through letters and correspondence, while Dr. Ambedkar was in London, working on his thesis at the London School of Economics. Well, they might have met personally during Dr. Ambedkar brief visit to Bonn on the occasion of his registration at Bonn University. But that is all speculation. Dr. Ambedkar never took up his studies in Bonn. As he did not sign any lectures or attend any classes, he was taken off the university register on 12.1.1922. Intentions and plans apart, Dr. Ambedkar's project of Sanskrit studies at Bonn University remained unfulfilled. German Indology, represented through Hermann Jacobi, certainly played a supportive role in Dr. Ambedkar's endeavor to study in Germany. But for his scathing attack on Hinduism as well as his most creative view of Buddhism he had to rely on translations and secondary sources. But his hunger for learning never subsided. He took up Pali studies in the 40s (Bellwinkel-Schempp forthcoming). Finally, his conversion to Buddhism as a universalistic and egalitarian religion was for him a liberating act as for many davits nowadays. Isn't his conversion to Buddhism the greater event to be commemorated by German Indology and Sanskrit studies? * I am grateful to Dr. Thomas Becker and Herron Johannes Ahrens for their kind help. Marem Bellwinkel-Schempp maren.bellwinkel@schempp.info Next pages: Handwritten curriculum vitae and letter of intent of Dr. Ambedkar*

[120] *Law , Narendra Nath "Age of the RV", Firma KL Mukhopadhyay, Kolkata, 1965,*

2000 BCE The first Solar- Lunar calendars in Egypt and Mesopotamia
Stonehenge Sanctuary (England) Constellations drawn up by the ancient astronomers
1861 BCE to 1350 BCE – if we accept δ Capricorni as Dhanishta, then the winter solstice occurs in Dhanishta in 1861 BCE. If β Delfini is chosen as Dhanishta then it gives a date of 1350 BCE
1861 BCE to 1350 BCE Maitrayana *Brāhmaṇa* 6.14 , the Uttarāyana point, the winter solstice has been reported in the middle of sravishta
1814 BCE According to Garga Parasara, the Sun begins its Southerly travel at the middle of Āśleṣā Nakṣatra while the Uttarāyana or Northward trek towards the Summer solstice commences at the beginning of Dhanishta. Today the Sun begins its Uttarāyana at Mūla Nakṣatra. Thus the commencement of Uttarāyana has moved back 4 Nakṣatra or (4/27)25812 = 3824 years, which gives a date of 1814 BCE[121].
1255 BCE King Suchi of Magadha sets forth Jyotiṣa Vedāńga*,* dating it by including an astronomical note that summer solstice is in Āśleṣa Nakṣatra.
8TH TO 9TH CENTURY BCE – A list of 8 Hsius appears in the record of the Book of odes (Shih Ching)
850 BCE The Chinese are using the 28-*Nakṣatra* Zodiac called Hsiu, adapted from the Hindu Jyotiṣa system." (Siddharth, p.87) .Prior to that they used a 23 Nakṣatra system. The Weber manuscript discovered around 1890 CE near Yarkand in Sinkiang Province, describes the 28 Nakṣatra system of the Atharva Veda, as described by an Indian scholar Pushkarasardi (see SB Roy Ancient India). A full list of 28 Nakṣatras in a record called Huai Nan Tzu (2nd century BCE) as a lunar zodiac.[122]
700 – 800 BCE – Mulapin clay tablets appear listing 18 constellations, there is agreement only on 6 or 7 of them, with corresponding Nakṣatras in the Indic system. However, Mrigaśīrṣā, Ardra, ĀŚleṣā, Hasta, Mūla, Abhijit and Sravishta differ completely from the Babylonian system. Thus the Indian Nakṣatra system is not only different from the Babylonian but it -predates it by several centuries. To this day, not a single document has been found in ancient Babylon, listing all 27 or 28 Nakṣatras.
VIII century BCE – Hesiod's works and days
VII century BCE – Mulapin- Babylonian astronomical text survives today in several copies on clay tablets
VI century BCE -Pythagoras and Thales of Miletus speculate that the Earth is a sphere. Thales was responsible for importing mathematics and astronomy into Ionia
VI century BCE – There is a theory that Pythagoras (Pitaguru) was of Indian origin
500 BCE – Kidinnu or Cidenas , Babylonian Astronomer, signifies the beginning of computational astronomy in Babylon
V Century BCE Meton (Metonic cycle) of 19 years
330 BCE Aristotle's on *Heavens*
280 BCE Aristarchus of Samos suggests that the Earth revolves about the Sun *(heliocentric*

121 Abhyankar, K.D, and Sidharth, B.G. Treasures of Ancient Indian Astronomy, Ananta Books Intl. Delhi, 1993.

122 Subbarayappa, BJ " Tradition of astronomy in India", PHSPC, Centre for the study of civilizations

concept of the Universe). **He also provides the first estimations on Earth-Sun distance**
240 BCE Eratosthenes of Cyrene (now Shahhat, Libya ?) measures the circumference of the earth with extraordinary accuracy by determining astronomically the difference in latitude between the cities of Syene (now Aswan) and Alexandria, Egypt
130 BCE Hipparchus is credited with the discovery of the precession of the equinoxes and develops the first star catalogue and charts (- 1000 brightest stars) but does not have the tools necessary to estimate the precession very accurately.
45 BCE The introduction of the Julian calendar (purely Solar calendar) to the Roman Empire upon the advice of the Greek astronomer Sosigenes to Julius Caeser, by then the Pontifex Maximus
CE 140 Ptolemy suggests the geocentric theory of the Universe in his famous work *Mathematike Magali Syntaxis* widely recognized from its Arabic translation as Al*Majisti*. The Almagest is however, an accreted text including the contributions of many other civilizations and not just the original text of Ptolemy's Syntaxis. There are currently no vulgate manuscripts of Ptolemy's version of the Syntaxis that can be dated to the 2nd century of the common era. Until that is done, it would be the height of folly and utterly disingenuous to attribute everything in the Almagest (as it is described today) to an individual named Ptolemy in the 2nd century of the Christian era. It has been reported that Kunitsch[123] has analyzed the different contributions to the Almagest. CK Raju summarizes the arguments in CFM in favor of the proposition that there does not exist today a vulgate text which is close to the original publication of Ptolemy. We will highlight the crux of the argument in the chapter on transmission of knowledge.
CE 332 *Varāhamihīra* alludes to Summer Solstice in Punarvasu, during his time as opposed to the SUSOL in Āśleṣā during the time of the Vedāṅga Jyotiṣa (which is 2 Nakṣatras away or 1910 years (26$^{o.}$67* 71.7 ~ 1910). This is confirmed by the table on Astronomical Observations(RNET) retrodicted by Planetarium software (Voyager 4.5) in chapter
CE 1202 Leonardo of Pisa (known as Fibonacci), after voyages that took him to the Near East and Northern Africa, and in particular to Bejaia (now in Algeria), wrote a tract on arithmetic entitled *Liber Abaci* ("a tract about the abacus"), in which he explains the following: "My father was a public scribe of Bejaia, where he worked for his country in Customs, defending the interests of Pisan merchants who made their fortune there. He made me learn how to use the abacus when I was still a child because he saw how I would benefit from this in later life. In this way I learned the art of counting using the nine Indian figures... The nine Indian figures are as follows: 987654321 [figures given in contemporary European cursive form]. "That is why, with these nine numerals, and with this sign 0, called zephirum in Arab, one writes all the numbers one wishes."[124]
CE 1400 – Decimal place value system gradually and slowly achieves acceptance in Europe. Algebra and trigonometry follow.
CE 1560 – Christoph Clavius, the first known German mathematician, sends several specially

[123] *Kunitsch, Paul Der Almagest (2974), has a discussion on the variations between the Arabic Versions and the original Greek version of Ptolemy*

[124] *Boncompagni (1857), vol.1*

trained Jesuits to Kerala to learn the Jyotiṣa, principles of navigation, accurate trigonometric tables. We learn of their desire to learn these topics from Matteo Ricci's[125] diary
CE 1582 – Gregorian Calendar adopted , 11 days in October disappear
CE 1752 – The English speaking world falls in line with the Gregorian calendar
CE 1917 – Russia adopts the Gregorian calendar. after the revolution
CE 1956 – Republican India adopts a largely Gregorian calendar as the Indian national calendar

The Sūrya Siddhānta, a document evolved from roughly same period, states that Sun was 54° away from vernal equinox when Kaliyuga started on a new Moon day, corresponding to February 17/18, 3101 BCE, at Ujjain (75°47' E, 23° 15' N).

Varāhamihīra (circa 560 CE), another famous astronomer, stated that 2526 years before start of *aka* count (either Śalivāhana Śaka starting in 79 CE or *Vikrama Śaka* starting in 57 BC or the Śakanripa Kala of the Persian King Kuru 550 BCE) [Brihat Saṃhitā] as per text below.

आसन्मघासु मुनयः शासति पृथ्वीं युधिष्ठिरे नृपतौ।
षट् द्वियुक पङ्चद्वियुतः शककालस्य राज्ङश्च॥
बृहत् संहित १३–३।

When Saptariṣi (Ursa Major, The Great Bear, and Big Dipper) was near *Magha,* Yudhistira was king 2526 years before *Śaka* time. Presently, traditional *Sanatana Dharma* followers consider that *Kaliyuga* started

124 Matteo Ricci an Italian Jesuit Missionary who with Michael Ruggieri opened the door to China for evangelization but more importantly from the perspective of determining the means by which knowledge was transmitted to Europe, acted as the transmitter of such knowledge from the east to the West. Born in Macareta, Italy on October 6, 1552. Went on to study law at Rome, where in 1572 he joined the Society of Jesus (SJ). He studied mathematics and geography at the Collegio Romano, under the Directorship of Clavius between 1572 and 1576 and in 1577 left for the Indies via Lisbon, the customary departure point. He arrived in Goa in 1578 where he taught at the college until 1582 and went on to China to establish the Catholic Church there. But it is the 4 years he spent in Goa and Malabar that interests us. The Portuguese if we recall had a large presence in Cochin (until the protestant Dutch closed down the Cochin College in 1670. So Ricci was sent to Cochin and remained in touch with the Dean of the Collegio Romano. He explicitly acknowledges that he was trying to learn the intricacies of the Indian calendrical systems from (Brāhmaṇas. See for instance, Ricci (1613). The task of preparing the Panchangas (literally the five parts) which were more than a calendar and would properly be referred to as a almanac,, was the provenance of the Jyotishi pundit who was well versed in the Calendrical algorithms to devise the proper almanac for his community. Each community (for example farmers) had differing needs for their almanac and hence the need for a Jyotishi Pundit. Today this is done with calendrical software with the help of the ephemeris published by the Government of India annually. The standard treatises used then were the Laghu Bhaskariya and in Kerala the karanapadhati. So, it is clear that Matthew Ricci was trying to contact the appropriate Brāhmaṇas, as he explicitly stated that he was trying to do, and it appears unlikely that he did not succeed in imbibing these techniques from them.

at 3101 BCE, when Sri Kṛṣṇa passed away, and that *MBH* war occurred in 3138 BCE. Millennium year 2000 CE is *Kali* 5101.

There is a suspicion, that somewhere along the historical past; there was confusion in the interpretation of the various definitions of the year, which has resulted in such long periods being assigned to the Yugas such as Kaliyuga. We will discuss later the relevance of the divine year which is mentioned as being comprised of 360 tropical years. For example the duration of a Kaliyuga in Divine years is a more manageable 1200 years and the entire Mahāyuga is 12000 years which is of the same time scale as the beginning of river valley civilizations, if we assume that there was a confusion regarding the interpretation of the year. Certainly, the exact meaning of such large epochs has puzzled almost everybody. B.G. Siddharth has discussed this in a fascinating book titled "The Celestial Key to the Vedas[126]". He proposes that the Yuga of 432,000 years is almost exactly divisible by the eclipse cycle of **6585.32^{d} (18^{y} 11.33^{d})**, the so called Saros cycle. Secondly, the period of 4,320,000 years is almost exactly divisible by the Precessional cycle of **25,867^{y} (*167).**

So now, we have the glimmerings of comprehension as to the large numbers of years in a Chaturyuga. The meanings behind these various numerical relationships is discussed by BG Siddharth in a more elaborate manner in Chapter 6 of his book We will discuss this later. We remain eclectic in that we are not certain, whether it is the attempt of the ancient Indic to define geologic time scales associated with the beginning of recorded history or the attempt to commence an era with a commensurate magnitude (LCM) that caused confusion. However, it has invited the ridicule of some in the occident such as Thomas Babington Macaulay and has prompted him to characterize the entire literature of India as being worthless[127].

HOW OLD IS THE UNIVERSE, KALACHAKRA, THE YUGA CONCEPT, HINDU COSMOLOGICAL TIME

The Hindu Calendar or more appropriately Almanac (also known as the Panchānga) currently in practice reckons time in terms of very large cycles called Kalpa (4.32 billion years) consisting of 14 Manvantara (Manvantaras or age of Manu,~ 308 million years). A Manvantara is made up of 71 Mahāyugas (Mahāyuga = great Yuga consists of 4 yugas: Krta, Treta, Dvāpara and Kali). Kaliyuga is equivalent to

[126] B G Sidharth ibid

[127] There are other instances in History where ignorance and the destruction of another civilization has been eulogized with great approval and vigor but Lord Macaulay deserves the responsibility for what will be the epitaph to the Colonial paradigm, the willful de-legitimization of an ancient tradition and civilization to the extent that it has been displaced by an Occidental veneer with which most in India have little familiarity or knowledge. It is also
Brāhmaṇas
a historical fact that Britain thereupon set out to colonize Indian minds no less than Indian space, thereby producing what Sudipta Kaviraj has characterized, without much exaggeration, as ''an epistemic rupture on the vastest possible scale—one of the greatest known in history,'' whereby Indian forms of thought of great antiquity and complexity were summarily disqualified from public use" in Commerce, administration, and academia. Quoted by Sheldon Pollock, Columbia University.

432,000 years and 1 Mahāyuga = 4.32 million years or 10 Kaliyugas. The concept of the Yuga, arose from the near commensurable property of the periods of revolution of the Sun, the moon, and the five planets that could be observed by the naked eye. This system appears to have been in use since the days of the Epics and Purāṇas, and attested in the Siddhāntas. However, the earliest Vedic Calendar was based on a cycle also called Yuga, but consisting of only five years. This ancient Vedic Calendar was a lunisolar calendar and used two intercalary months in a five year period and has often been criticized as being very crude.

First we have Kalpa, a day (and a night) in Brahma's 'life' or 4320 million earthly years, and a night of equal length. During the day he creates and during the night he absorbs to begin the cycle each Brahma day. Each kalpa is divided into 14 Manvantara or 308.448 million years we are supposed to be in the seventh Mānvantāras of Vaivasvata Manu. Each Manvantaras contains 71 Mahāyugas, plus 1 Krtayuga ,and each Mahāyuga is divided into 4 yugas — Krta, Treta, Dvāpara and Kali of 4800, 3600, 2400 and 1200 divine years of the Gods, each of which = 360 human years. We are at present in the Kaliyuga which began in 3101 BCE the traditional year of the MBH war.

TABLE 2 YUGA PERIODS IN YEARS MENTIONED IN THE VANAPARVA OF MBH

Krtayuga	4800 years
Treta yuga	3600 years
Dvāpara Yuga	2400 years
Kali yuga	1200 years
Total	12000 years

Commentary[128]: Perhaps the most vivid description of this key cycle is the one provided by the story of the bull Dharma as narrated in Bhāgvata Purāṇa 1, 4:17 ff. There is depicted how Dharma, "Religion," steadily loses, one by one, his four legs on every successive age: In Satya–yuga, the primeval age in which mankind fully keeps the religious principles, and which is characterized by virtue and wisdom, he is supported by the four principles of austerity, cleanliness, truthfulness, and mercy; in Treta–yuga, the Era in which bad habits appear, he loses austerity; in Dvāpara–yuga, as bad habits proliferate, he loses cleanliness; and in Kali–yuga, the Era of quarrel and hypocrisy and of the biggest degradation and spiritual darkness of all four, in which we are now, he additionally loses veracity and is only supported by mercy, which declines gradually as the time of devastation closes by.

The beginning of the Kali–yuga is established in the Sūrya–Siddhānta, which is perhaps the oldest astronomical treatise in the world as the midnight of the day that corresponds in our calendar to the 18th February of 3101 BCE, when the seven traditional planets, including the Sun and Moon, were aligned in relation to the star Revati (identified as eta Piscium). While this date certainly sounds implausible, it was not long ago confirmed by astronomical calculations made by computer software published in the United States by Duffet-Smith.

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[128] *Miguel Goitizolo http://miguelgoitizolo.ws/TheHinduCycles.htm*

"Let's take a look now into the bigger cycles. If we remember, a Brahma's day consists of one thousand Mahā–yugas, and his night of an equal number of them. The "day" and "night" therefore are 4,320,000 x 1,000 x 2 = 8,640,000,000 common years long. Now, since Brahma lives one hundred of his years (of 360 "days" each), a simple calculation (8,640,000,000 x 100 x 360) unveils the total length of the immense cycle of cosmic manifestation: 311,040,000,000,000 common years – a duration that theoretically is just that of a breathing period of the Mahā–Vishnu, the Great Universal Form, and symbolically corresponds to the two complementary phases into which each cycle of manifestation is divided – in this case a dual, alternating movement of expansion and contraction, exhalation and inhalation, systole and diastole.

As to the kalpa of 4,320 millions of years – an appropriate study of which would indeed require a whole treatise it is clear that its frequent identification by Western scholars with the total cosmic manifestation has been overrun by the age that modern science attributes to the universe, an age that would place it rather on a planetary level or, at best, galactic. And in effect, according to the orthodox Hindus for whom the kalpa is simply synonymous with a Brahma's day without its corresponding night, the end of the kalpa comes with a partial dissolution of the universe by water; and as regards its duration, the doctrine abides strictly by the aforementioned figure. Now, the fact that this length of time virtually matches the 4,500 millions of years estimated by modern science for the Earth's age (let alone the "ultimate" figure of 4,320 million), certainly points to the possibility that it represents the lifetime of our planetary system; if so, it would not be unlikely that the Earth were currently very close to the end of a Brahma's day and that its corresponding night was now approaching, even if it takes ten or twelve millions of years yet to arrive. However, all this is not by far that simple: For one thing, the related texts are in some cases quite enigmatic as suggested, for example, by the reiteration of the phrase "Those who know..." (Bhagavad–Gita 8:17), so the possibility remains that the 4,320 millions of years do not actually mean the daytime but the full Brahma's day, so that the length of the daytime would be 2,160 millions of years, and an equal number of years that of the night. So here again, the possibility that the figures may have been somehow disguised should be taken into account.

Finally, the immensely vast length of $311.040 * 10^{12}$ common years that the texts implicitly assign to the great cycle of cosmic manifestation accommodates indeed comfortably the 15 billions of years estimated by modern physics as the age of the universe; and even if such length were deemed exaggerated – say it was a thousand times lesser, i.e. the actual figure was only $311.040 * 10^{9}$ years, which is certainly not impossible if we stick to the foregoing considerations – even so the 15 billions of years would fit comfortably within that period. At any rate, it would mean that our universe is still very young and that we are now, within the immense cycle of universal manifestation, virtually at the beginning of an expansion period.

And indeed, it is amazing that it took literally millennia for the modern scientific circles to again conceive this ancient notion of a universe that "breathes," i.e. a universe that has two phases, one in which it expands and the other in which it contracts; two phases which, by virtue of the correspondences to which cycles of any order of magnitude are subject, can be respectively assimilated to a Brahma's day and its corresponding night, as well as to both phases of what the Hindus call a Manvantara ."

THE MAHĀYUGAS ARE MENTIONED IN THE MAHĀBHĀRATA

The notion of the Mahāyugas is expressed in the MBH in 2 separate places, the Vanaparva , chapter 18 and in the Harivamsa, and does not occur explicitly in the Saṃhitā epoch of the Veda. BG Siddhārth, the internationally known Astrophysicist and Director of the Birla planetorium in Hyderabad, feels that it appears in an encoded form in RV (10.11.117.8). It also occurs in the Śatapatha Brāhmaṇa[129],[130], the Bhāgavata Purāṇa, and the Markandeya Purāṇa. If we indulge in the hubris that only the Indians resorted to such large timescales we would be grievously wrong. Almost all the ancients exhibited this propensity, for what appeared to be valid reasons.

The Harivamsa is an appendix to the MBH. However the number of years are different. In the Vanaparva, the division of the yugas is the usual one and the day of Brahma is also stated to be of 1000 yugas as in the Sūrya Siddhānta. But the number of years in the yugas is different from the one mentioned in the Sūrya Siddhānta. The number of years mentioned in each yuga is given in Table 2.

THE POSTULATION OF THE DIVYABDA OR A DIVINE YEAR

If we treat these as divine years we get the same number of years as the Sūrya Siddhānta. However, there is no mention of divine years in the Vanaparva citation. It clearly mentions that the total length of years is much smaller than in the SūryaSiddhānta.

The beginning of the Kritayuga Is stated to take place when the Sun, Moon and Jupiter come in conjunction with the Puṣya asterism. This theory Is certainly different from that of the Sūryaslddhanta. In the above theory. only the three planets are stated to be in conjunction. The measure of this Yuga will naturally be of smaller size. In the Sūryaslddhanta the conjunction of all the seven planets in the Ashvlni Nakṣatra marks the beginning of the yuga. Its measure will. therefore. be of much larger size. It is. therefore. evident that the theory of the Sūryaslddhanta is a later development. The improvement in the old theory has been made only by making a slight addition. The concept of the divine years has been introduced in the system so that the period of each yuga becomes very large without tempering with the old system of division. To correspond with the new improvement, the conjunction of all the planets was made the basis of marking the beginning of the epoch. The division of the period of Brahma (1000 yugas) in the Manvantaras is also not met with in the above theory of the Mah3bharata which also seems to be of later origin.

In the Harivamsa Purāṇa, on the other hand, the yuga theory is exactly the same as given In the Sūrya Siddhānta. The divine year is defined first as of 360.0 years . Then the verses of the MBH as given in the Vanaparva mentioned above are reproduced ʹverbatim and one line is added stating that the above number of years tn a yuga (i.e. 12000) should be regarded as Dvine years Further. as in the

[129] N V B S Dutt" Manvantras and cyclic tectonic activity" paper presented at the All India Seminar on Ancient Indian Astronomy , B M Birla planetarium , Hyderabad, 1987
[130] Satya Prakash Saraswati "The critical and cultural study of the Śatapatha Brāhmaṇa " New Delhi, Govind Ram Haranand, 1988

Sūryaslddhanta. 71 Chaturyugas are stated to constitute a Manvantara and 14 Manvantaras are stated to constitute a Kalpa.[48] Here we have a potential solution to 2 riddles:

1. The riddle of the excessively large Chaturyugās which appear to be a later amplification, which in reality caused much misunderstanding and,

2. The riddle of the date of the Sūrya Siddhānta.

This is one possible solution to the riddle of the Mahā Yugas. We admit we know of no valid reason to assign such large numbers to the Chaturyugas, but then this raises the spectre of how so many of the ancients could be wrong in enunciating the Divine year and assigning these large numbers.

I found this explanation in the book by Sudhi Kant Bhardwaj[131] on the Sūrya Siddhānta

"The appearance of two distinct theories In the MBH and its appendix has brought us very near the solution of the riddle of the time of the Sūrya Siddhānta which has been puzzling the scholars throughout the ages. We can now definitely conclude that the Sūrya Siddhānta was written sometime between the period of the composition of the earliest part of the MBH and the period of the composition of its appendix known as the Harivamsa Purāṇa."

TABLE 3 COSMOLOGICAL TIME AS DEFINED BY THE ANCIENT INDIC AN ALTERNATE RATIONALE
1 Brahma Lifetime = 100 Brahma Years = 3.1104 $*10^{14}$ sidereal years
1 Brahma Year= 360 *8,640,000,000 = 3,110.4 $*10^{9}$ sidereal years
1 Brahma Day (day and night) = 2 Kalpa or 2 Aeons = 8,640,000,000. Sidereal years
1 Kalpa = 4,320,000,000 earthly years (Y) =14 Manus + 1Kritayuga = 1000 MY =14*71.4+.4 MahāYugas
We introduce the new definitions, which were in fact mentioned in the MBH VanaParva
Kaliyuga = = 1200 years (Y new) = 1 Yuga
1 MY = 10 KY
Dvāpara = = 2KY = 2400 Ynew
TretaYuga = 3KY = 3600 Ynew
Kritayuga =4 KY = 4800 Y new= 0.4 MY
1Manvantra (M) = 71 MY = 71*12000 Ynew = 852,000 Ynew (Age of Homo erectus)
Delay in creation = 47,400 divyabdas = 47400 (subtract this from the total as the time taken to furnish the apartment)
We will recapture the 360 factor to stay consistent with the cosmological time frames. This is consistent with the Harivamsa definition of a Brahma day.
1 Manu =(1M +1 KritaYuga)* 360= (856,800 Ynew) * 360 = 308,448,000 Ynew
1 Kalpa = 14 Manus + 1KritaYuga *360= 1000 MY = 12,000,000 DY = 4.32 billion*Ynew

[131] *Bhardwaj, Sudhi Kant., SūryaSiddhānta – An Astro Linguistic study, Parimal Publictons, New Delhi, 1991*

Y = Solar or tropical year
DY = 360 Y = divine year = Ynew
KY =12,000 = Kaliyuga
MY = 10 KY = Mahāyuga

Though there Is much controversy about the date of the MBH. yet the general consensus (?) is that the earliest part of the MBH was written in script that we use today (as opposed to being composed) in the 4th century BCE and was complete in its present form, including its appendix before the beginning of the Christian era. This is the last downward limit of the MBH. We can push this limit backward but accepting the average period as mentoned above, we can fix the terminus ante quem date of the Sūrya Siddhānta approximately as 200 BCE. The other details mentioned In the Sūrya Siddhānta also correspond to the same period. The language, In particular resembles that of the epic period. The selection of the Anushtup metre also suggests It to be the product of the same period because the later astronomical works are generally in the Āryā metre.

A non-vedic view of the time span of a yuga is given by Swami *Sri Yukteswar Giri*, the *guru* of *Paramahansa Yogananda*. This is detailed in his book, *The Holy Science*. According to this view, one complete yuga cycle is equal to one complete "precession of the equinox", a period of approximately 24,000 years. The ascending (Utsarpiṇī[132]) phase consists of a 1200 year Kali, 2400 year Dvāpara, 3600 year Treta and 4800 year Krita (Satya) yuga. The descending (Avasarpiṇī) phase reverses this order, thus both ascending and descending phases equal 24,000 years. According to calculations given in the book, the most recent yuga change was in 1699, when the Earth passed from the Dvāpara Yuga to Treta Yuga. We are in an ascending spiral right now, and will pass into the Satya Yuga in 5299 CE. According to the book, the motion of the stars moving across the sky (a.k.a.precession) is the observable part of the Sun's motion around another star. The quality of human intellect depends on the distance of the *Sun* and Earth from a certain point in space known as the Grand Center, Magnetic Center or Vishṇunābhi. The closer the Sun is to it, the more subtle energy the *Solar System* receives, and the greater is the level of human spiritual and overall development. As the Sun moves around its companion star, it brings us closer to or drives us farther away from Vishṇunabi, resulting in the rising and falling ages here on Earth.

Yukteswar tells us that the calendars of the higher ages were based on the Yugas, with each era named after its Yuga. Hence, the year 3000 BCE was known as descending Dvāpara 102 (because the last descending Dvāpara yuga began 102 years earlier in 3101 BCE). He stated that this method was used up until the recent Dark Ages, when knowledge of the connection with the yugas and the precession cycle was lost; "*The mistake crept into the almanacs for the first time during the reign of Raja Parikshit, just after the completion of the last descending Dvāpara Yuga. At that time Mahāraja Yudhisthira, noticing the appearance of the dark Kali Yuga, made over his throne to his grandson, the said Raja Parikshit. Mahāraja Yudhisthira, together with all the wise men of his court, retired to the Himalaya*

[132] *Utsarpiṇī is the ascending phase of the 24000 year cycle, progressing from Kali, Dwapara, Treta and Satya Yuga in 12000^{y} .see also Avasarpiṇī in glossary. see discussion in chapter III*

Mountains... thus there was no one who could understand the principle of correctly calculating the ages of the several Yugas". Thus, Yukteswar assumed that Raja Parikshit was not trained in any vedic principles even though he alone ruled the world many year. Thus, he interpreted that Yugas are not calculated correctly. Consequently, he gave the theory that when the Dvāpara was over and the Kali era began no one knew enough to restart the calendar count. They knew they were in a Kali Yuga (which is why the old Hindu calendar now begins with K.Y.) but the beginning of this calendar (which in 2011 stands at 5112) can still be traced to 3101 BCE, (3101+2011=5112) the start of the last descending Dvāpara Yuga. To this day there is still much confusion why the Kali era starts at this date or what the correct length of the Yugas should be. Yukteswar suggests that a return to basing the Yuga calendar on the motion of the equinox would be a positive step."

InferrIng from the occurrence of the word Rākṣasālaya. we have suggested above that the Sūrya SIddhanta was written after the Rāmāyaṇa. Some scholars put the date of the likhita or scriptural version of the Rāmāyaṇa as 100 BCE In this perspective. to fix the date of the Sūrya Siddhānta as 200 BCE poses some difficulty. But 100 BCE is the terminus ante quem of Rāmāyaṇa beyond which it cannot be carried downward. The upper limit should be much earlier. The MBH contains the Rāmopākhyāna. the narration of which exactly agrees with that of the Rāmāyaṇa story. We therefore strongly believe that the genuine part of the Rāmāyaṇa must have been composed orally in metre prior to the MBH."

TABLE 4 A DAY IN BRAHMA'S LIFE OF 1 KALPA
1 Kalpa = 4,320,000,000 earthly years (Y) =14 Manus + 1Kritayuga = 1000 MY =14*71.4+.4 Mahāyugas
Kaliyuga = 432,000 Y = 1KY = 1200 divine years (DY) = 1 Yuga
1 DY = 360 Y
Dvāpara = 864,000 Y = 2KY = 2400 DY
TretaYuga = 1,296,000 Y = 3KY = 3600 DY
Kritayuga = 1,728,000 Y =4 KY = 4800 DY = 0.4 MY =.4/71.4 = 5.6022408964e-3
Mahāyuga (MY) = 4,320,000 earthly years = 10 KY = 12000 DY aka Chaturyuga
1Manvantra (M) = 71 MY = 306.72 million years
Delay in creation = 47,400 divyabdas = 47400*360 = 1,706,4000 civil years (subtract this from the total as the time taken to furnish the apartment)
1 Manu = 1M + 1 Krita or Satya Yuga = 308.448 million years = 856,800 DY
1 Kalpa = 14 Manus + 1KritaYuga = 14*71.4 +.4 = 1000 MY = 12,000,000 DY = 4.32 billion
Y = Solar or tropical year
DY = 360 Y = divine year
KY = 432,000 = Kaliyuga
MY = 10 KY = Mahāyuga

WHAT WERE THE BASIC FEATURES OF THE VEDIC CALENDAR (4000 BCE) – INFLUENCED BY MONSOON

TABLE 5 HOW OLD IS THE SOLAR SYSTEM
As of Vaiśākhā pratipada of 2009 CE, May 1 we are in the second quarter of Brahma day**) द्वितिय परार्थ(** , called Shweta Varāha Kalpa, seventh Manvantaras named Vaivasvata and entered into the first quarter of the 28th Kaliyuga. Already 5110 years of this 28th KY have passed, so the time elapsed in this Kalpa is 6 Manus =1,850,688,000 Y = [6*(306,420,000+1,728,000)] = 6 Manus (includes 6 Jala pralayas or sandhis, periods between Mānvantāras) And 27 MY = 116,640,000 Y (27 * 4,320,000)=27/71.4M = 0.3781512605 M
Add 1 Jala Pralaya(depending on origin of cycle) = 1,728,000 Y or 1 Krita Yuga
And 28th (Krta+Treta +Dvāpara) = 3,888,000 Y (9*432,000) =0.9 MY =.9/71.4 = 0.012605042M
5110 Y of Kaliyuga = 5110 Y = 5110/4,320,000 MY = 1.1828703704 (10*-3) MY
the current year 2010 CE = 1,850,688,000 + 116,640,00 +1,728,000 + 3,888,000 + 5111 = 1 ,972,949,111 Y or Solar years or 1.972949111 Billion years
= 426+27+(.4*7) + .9 +.001182703704 = 456.701182703704 Mahā Yugas
Deducting 47,400*360 = 17,064,000, the time spent in creation gives 1,955,885,111
To put this in perspective, if we look at a galaxy 2 billion light years away (a unit of distance) we would be looking at an object in time contemporaneous with the age of ½ a Brahma day or the birthday of our Solar system. It is incredible that the Indic ancients were able to fathom such cosmological time frames merely by the use of Observational Astronomy, using just his naked eye, especially when it is recalled that the Romans had no name for a number greater than a thousand, and the state of Tennessee passed a law saying that the value of PI should be legislated to be 3, as late as the 2nd half of the nineteenth century.

The Vedic Calendar was a lunisolar calendar . It comprised of 3 types of years; Solar Year - a year of 360 civil days (12 māsa with 30 days each), civil year and a Lunar year. We quote Prof K D Abhyankar who gives a very cogent rationale for the subsequent steps that the Indics took *"The year or the Samvatsara is the most important constituent, because it controls the seasonal growth of crops and other vegetation that are so important for human survival. It is, therefore, necessary to determine the length of the year. It was discovered quite early that the seasons are related to the position of the Sun in the sky at noon, which in turn is related to the northward and southward motion of the rising Sun on the eastern horizon. Such observations can be easily made with the help of a stick called a* ***Yupa****. Hence the two halves of the year namely the Uttarāyana and the Dakṣiṇāyana, became the two basic divisions of the year very early in history. In India, the beginning of Uttarāyana has used for starting the year from remote antiquity as is from the Vedāńga Jyotiṣa calendar and Aitareya Brāhmaṇa 18.18 and 18.22, where it is stated that on Viṣuvadina, which occurred in the middle of the year, the Sun reached its maximum altitude, that indicated the beginning of Dakṣiṇāyana. In fact, this was the practice of the ancient civilizations. For example, the Gregorian calendar, which begins the year only ten days after the winter solstice, is a relic of this ancient practice.*

The observations of Uttarāyana and Dakṣiṇāyana indicated that the year contains roughly 360 civil days or of Ahas (days) and Rātris (nights) together or an Ahorātri, a Nychthemeron. Considering another observed fact that the lunar phases repeat after a period of about 12 months of 30 days, it simple and convenient to divide the year of 360 days 30 days each. There are several quotations in the literature which support that the earliest calendar was based on this plan. Some of these are given in the next section.

Lunar years are called Vatsara, are of 5 types **Samvatsara, Anuvatsara, Parivatsara. Idvatsara, Idāvatsara. Anuvatsara is also called Iduvatsara**. The names of the thirteen months are given in **Śatapatha Brāhmaṇa** (3.10.1). The six seasons are also listed (Vasanta etc).The Taittiriyā Brāhmaṇa lists 24 half months (1 fortnight). The names of the Lunar months are determined by the Nakṣatra in which the Moon is located during the Pūrṇima day. While the Solar year is known to be approximately 365.2425 days, (5 days are added at the end of 360 days, interspersed with 6 days (atirātra). Note the similarity between the Vedic and the Egyptian Calendar (Chapter 10).

S Balakṛṣṇa[133] of NASA explains this in a very apt manner "The Chandramāna lunar calendar system keeps a natural cyclic count of days using two Moon based properties described below.

"The first property is that the Moon functions as an astronomical day count clock in which the Moon is the pointer and the stars are numerals in the sky pointed to by Moon each day of the lunar month. The astronomers of Vedic period identified this approximate 13 degree movement of the Moon between successive days and named the 27/28 stars pointed to by Moon on a daily basis over a rotation as 27/28 Nakṣatra's, corresponding to little less than a lunar month. Thus a Nakṣatra shift corresponds to the traverse of the Moon over approximately one solar day.

The second property is the size of the fractional Moon exposure to the Sun (is easily discernible to the naked eye and) can indicate a day count and is defined as a Moon day or Tithi. Thirty tithi's are defined in a lunar month, each Tithi being smaller than a solar day. Fifteen are identified as Śukla pakṣa or ascending fortnight and next fifteen are called Kṛṣṇa Pakṣa or descending fortnight.

This system of day count calendar keeping is traceable to the Veda's. A study of the Veda's, Brāhmaṇas and Āraṇyakas points exclusively to the use of a lunar pointer as the primary calendar in the Vedic periods. Pūrnamasya a time at which earth, sun, Moon are aligned is a time of singularity used for religious purposes and formed the unit of half a month and is used in RV. The Vedas also refer to solar events such as Āyanas, and Vishuvat-Sankramana's as solar singular events. Āyana means Solstices when apparent North-South movement of Sun reverses, usually occurring on June 21 and Dec 22. Vishuvat means equal or the spring and fall equinox's when daytime is equal to nighttime, usually occurring on March 21 and Sep 21. There are Vedic references to solar singularities with corresponding solar/lunar pointed star locations.

The six-season definition is unique to Vedic system and is not found in any other recorded culture or system. These seasons are Vasanta, Grīshma, Varṣa, Sharad, Himavanta, and Shishira each season being about two Moon cycles. It is in the Taittiriyā Saṃhitā (Kṛṣṇa Yajurveda) and in the Atharva Saṃhitā 19th kānda, 7th Sūtra that an explicit first definition and identification of the twenty- seven (28) Nakṣatra's is available. "

Intercalation with a thirteenth month takes place on the 6th year.

[133] *S Balakrishna 'NAMES OF STARS FROM THE PERIOD OF THE VEDAS", http://www.vedicastronomy.net/stars_bharatheeya.htm*

There is a point to make about the mention of the seasons in the Veda and that is the fact that India is a tropical country and does not have the same seasonal pattern as the countries of Europe, which are in the temperate zone and have four seasons or those in West Asia which may have only one hot season. In the Polar Regions we have only two seasons, summer and winter. In the equatorial belt we have only one hot and humid season throughout the year. It is only in the lands of the monsoon climate like India and Mexico that we experience three seasons of hot, rainy, and cold weather, which are further subdivided into 6 seasons. It is appropriate to comment on this, since it precludes the possibility of the Veda having been composed elsewhere.

The prediction of the monsoon is critical to agriculture in India and along with the perceived need to perform sacrificial rituals at the accurate time, to placate the Deities so that they do not fail in their regularity, was the basis for calendrical astronomy in India It is clear that the development of the Calendar was done by people living in India and was unique to the subcontinent. This is one more argument in favor of the unique development of astronomy in India ever since the dawn of civilization and is not seen elsewhere.

There are several quotations in the RV which support the notion that the earliest calendar was according to the above principles.

RV1.164.11

द्वादशारं नहि तज्जराय वर्वर्ति चक्रं परि द्यामृतस्य ।

आ पुत्रा अग्ने मिथुनासो अत्र सप्त शतानि विंशतिश्च तस्थुः ॥११॥

Dvādaśāraṃ nahi tajjarāya varvarti chakraṃ paridyāmṛutasya |

Ā putrā agne mithunāso atra sapta ṣatāni viṃṣatiṣca tasthuh

The wheel of time having twelve spokes (revolves around the heavens, but it does not wear out. Oh, Agni, 720 pairs of sons (ahoratras) ride this wheel

RG Veda 1.164.48

द्वादश प्रधयश्चक्रमेकं त्रीणि नभ्यानि क उ तच्चिकेत ।

तस्मिन्साकं त्रिशता न शङ्कवोऽर्पिताः षष्टिर्न चलाचलासः ॥४८॥

Dvādaṡa pradhayaṣchakramekaṃ trIṇi nabhyāni ka u tachchiketa |

Tasminsākaṃ triṣatā Na ṣaṇgkavo arpitāh ṣaṣţirna chalāchalāsah ||48||

Twelve are the fellies, and the wheel is single; three are the naves.

What man hath understood it?

Therein are set together spokes three hundred and sixty, which cannot be loosened.

त्रिणि च वै शतानि षष्ठिश्र्च संवत्सरस्याहानि सप्त ।

च वै शतानि विंशतिश्च संवत्सरस्यहोरात्रयः ।।

Triṇi cha vai ṣatāni śaśţhircha saṃvatsarasyāhāni sapta |

Cha vai ṣatāni viṃṣatiṣcha saṃvatsarasyahorātrayah ||

A year has 360 days … A year has 720 days and nights together.
This was the first approximation, with 12 months; each comprising of 30 days. This was the first step in defining a year. But by this time it was noticed that the year was **slightly longer than 365 days**. During these 'extra' days they performed sacrifices until they reached the day of the solstice, which was observed to be at a certain Nakṣatra, and then they would begin the new year of 360 days again. It was soon determined that 4 days was insufficient while 6 days were too many. This is also confirmed in the RV in 1.164.14

सनेमि चक्रमजरं वि वावृत उत्तानायां दश युक्ता वहन्ति ।
सूर्यस्य चक्षू रजसैत्यावृतं तस्मिन्नार्पिता भुवनानि विश्वा ॥१४॥

Sanemi chakram ajaraṃ vivāvṛta uttānāyāṃ daṣa yuktā vahanti |
sūryasya chakṣūrajasaityāvṛtaṃ tasminnārpitābhuvanāni viṣvā ||

Once it was understood that the year was comprised of 365 days, they then went about synchronizing the phases of the Moon by adding an intercalary month of 30 days after 6 years. This is the import of the following sloka in the Atharvan Veda.13.3.8

अहोरात्रैर्विमितं त्रिशदङगं त्रयोदशं मासं यो निर्मिमीते ।

Ahorātrairvimitaṃ triṣadagaṇga trayodaṣa māsaṃ yo nirmimīte I

अहोरात्रि (ahorātri) – Nycthemeron – a day and a night of 24 hours

He who metes out the thirteenth month, constructed with days and nights, containing thirty members.

KNOWLEDGE OF RATE OF PRECESSION DURING ERA OF RV

Before demonstrating the unmistakable fact of the precession inherent in the cosmological time cycles, it would be of interest to the reader to see how the Western translators of the Sūrya Siddhānta made the choice to take the line of least resistance by assuming that the Indics were ignorant of the distinction between Sidereal and Tropical years and of the effects of the Precession.

To make such a division accurate, the year ought to be tropical, and not the sidereal; but the author of the Sūrya-Siddhānta has not yet begun to take into account the precession…The earliest Hindu astronomers were ignorant of, or ignored, the periodical motion of the equinoxes…

Again this opinion is in error. If Burgess and Whitney were not so blinded by hubris they might have been able to improve their knowledge by careful study of the Sūrya-Siddhanta. The precession is clearly derived from the cosmological time cycles as shown below. The Chaturyuga of 4,320,000 years is the unit of reference for determining the rate of precession used in the construction of the Hindu cosmological time cycles.

The Indics of that era postulated a constant rate of precession equal to 50″.4 = 0°.014 = $^{7}/_{500}$ degrees of precession per sidereal year. This is the same as one degree of precession in $71^{3}/_{7}$ = 71.42857 sidereal years. This compares very favorably with the modern value of precession determined by Al Tusi which is 71.6 years. This correlates to the cosmological time cycles as follows:

One manu = 71.4 MY (Mahāyuga = Chaturyuga)

$^{1}/_{14}{}^{th}$ of an introductory dawn = 0.02857 X Chaturyuga
$^{1}/_{14}{}^{th}$ kalpa = 71.42857 X Chaturyuga

In the intervall of $^{1}/_{14}$th kalpa there are:

($71^{3}/_{7}$) × 4,320,000 × 0°.014 = 4,320,000 degrees of precession = 12,000 precessional years

From table one we see that a period of one **Chaturyuga (or 1 MY)** is **4,320,000** years and is equivalent to 12,000 divine years. Is it just a happy coincidence that the Cosmological Time Cycles agree with the precession? Burgess and Whitney would probably think so. Other related values of interest are:

1 precessional year (Great Precessional Cycle) = 25, $714^{2}/_{7}$ sidereal years

7 precessional years = 180,000 sidereal years

7 × 18 (126) cycles of the 3rd mean motion of the Sun

7 × 24 (168) precessional years

1 Chaturyuga = 168,000 precessional years

1 kalpa = (4,320,000 ÷ 168) × 0°.014 = 360°

TABLE 6 VEDIC CALENDAR ANALYSIS		
Vedic calendar analysis		year number
number of 30 day months = 73	73	
number of days in Vedic yuga	2191.4532	
total number of days = 2190	2190	
But the six years of seasons have approximately = 2191.4532^{d}, so there is a shortfall of approximately 1.4532^{d}	1.4532	6(intercalary month)
In 3 yugas the shortfall will be	4.3596	18
days per year = 365.2422	365.2422	
Vedic calendar days = 360	5.2422	
shortfall per year = 5.2422		
In 5 years the shortfall will be 5.2422*5	26.211	23(intercalary month)
Add the shortfall from the previous yugas	30.5706	
Add 1 intercalary month in the 23rd year, shortfall. Start the next yuga immediately	0.5706	23
in the next two yugas error increases to	3.477	36
add 1 intercalary month in the 40th year, the 5th year of the 7 the yuga, error is	-0.312	40(intercalary month)

DERIVATION OF THE TROPICAL YEAR

In a Chaturyuga there are: 4,320,000 sidereal years = (4,320,000 + 168) tropical years, where 168 is the number of precessional years. Therefore:

1 tropical year = [4,320,000 × (366.2563795… −1)]/4,320,168 = = 365.2421756 mean solar days.

It has been shown conclusively that the Hindu Cosmological time cycles are based upon the diurnal motion of the Earth in reference to any particular fixed star, hence it is purely of sidereal origin. The later practice of adopting the ahargana or "heap of days" is based upon solar and civil day reckoning which is of obvious practical value for calendrics. The sidereal basis of the cosmological time cycles is without question the oldest known positive proof of the origin for the sexagesimal number system.

ANALYSIS OF THE VEDIC CALENDAR

Number of 30 day months = 73
Total number of days = 2190

But the six years of seasons have approximately = 2191.4532, so there is a shortfall of approximately 1.4532^d

So at the end of 3 yugas we have a shortfall of 3*1.4532 = 4.3596^d.

In the next 5 years of the 4th yuga , there would be an additional accrual of 26.211^d which now adds up to 30 days, add 1 intercalary month at the end of the 40^{th} year and close the 7h yuga at that stage. Thus we have a cycle of 40 years, which is related to the Venusian cycle, as follows:

8 sidereal/tropical years of ~$\mathbf{365.25^d}$ = $\mathbf{2922^d}$

5 synodic periods of Venus of 583.92^d = $\mathbf{2919.6^d}$

13 sidereal periods of Venus of 224.7^d = $\mathbf{2921.1^d}$

So the relative position of the Sun, Venus, and the stars would repeat closely 5 times during a 40 year period.

During the Mahāshivarātri/Rohiṇi Era, around 3000 BCE the positions of the 4 cardinal points were as follows (comparing with Tables 2, 4 and 6 in Chapter VII). Of course once you locate one of the Cardinal points, the rest are determined automatically, as a first order approximation.

TABLE 7 POSITIONS OF THE CARDINAL POINTS DURING THE ROHIṆI ERA	
Winter Solstice	Satabhisaj (Abhyankar suggests Formalhout α PsA)
Vernal Equinox	α Tauri Aldebaran Rohiṇi
Summer Solstice	δ Leoni Pūrva Phālguni
Autumnal Equinox	**Jyeşţha**

The Nakṣatras of the 4 cardinal points are depicted in the Mohenjo Daro seal #420 popularly referred to as the Proto Shiva seal. The central figure of this seal is the Prajāpati Brahma and it is surrounded by 4 animals representing the four zodiacal constellations. They are the Vernal equinox at Rohiṇi in Vrishabha; Summer solstice at Leo in Simha represented by a Tiger instead of Lion; autumnal equinox at Jyeşţha in Vrsacika (Tilak's Vrśākapi), represented by an elephant as it looks like Ganesa with an elephant trunk; and Winter solstice at Satabhisaj represented by one horned rhino for the single star Formalhaut. To quote David Frawley "one of the most important mathematical contributions of ancient times is the idea of a Zodiac or wheel of heaven of 360 degrees. This discovery is usually attributed by Western scholars to the Babylonians of around 400 BCE.



FIGURE 2 MOHENJODARO, THE PRAJĀPATI SEAL

However, the symbolism of 360 relative to a wheel of heaven is common in Vedic literature back to the RV itself, the oldest Hindu text which ranges from 7000 BCE to 4000 BCE. 360 is an important number for the Vedic mind. Therefore, along with the decimal system and the discovery of zero, the 360 degree Zodiac should be credited to India. The timing of these discoveries also needs to be examined as a forensic effort much as we would go about determining the date of an event such as a failure of an engineering system. Our understanding of Vedic chronology and the age of each of the Mandalas in the RV, indicates that the RV was in its present state by 4000 BCE[134]

TABLE 8 VEDIC CHRONOLOGY CORROBORATED BY ASTROCHRONOLOGY

Era	Epoch	winter solstice	Year beginning	Vernal equinox
Aṡvini/Pusya	7300 BCE	Aṡvini	Vaiśākhā S1[135]	Pusya
Revati/Punarvasu(ADITI)	6050 BCE	Revati	Chaitra S15	Punarvasu
Agastya/Rāmāyaṇa	5000 BCE	Uttara Bhādrapadā	Chaitra S1	Ārdrā
Pūrva Bhādrapadā, Orion	3835 BCE	Pūrva Bhādrapadā	Phālguna S15	Mrigaśīrṣā,
Mahāshivarātri,	3250 BCE	Satabhisaj	Phālguna S1	Rohiṇi

134 see for instance the number of markers that attest to such a dating in Table 1 of this chapter

135 We will denote the Shukla Pratipada (new moon) to Pūrṇima (full moon) by S1 to S15 and Krsna pratipada to Amavasya by K1 to K14 and K30 respectively see chapter II

Rohiṇi				
Maghā, Krittika	2330 BCE	Old Dhanishta	Māgha S15	Krittika
Vedāṅga Jyotiṣa	1400 BCE	new Dhanishta, Sravishta	Māgha S1	Apabharani

In addition, the twelve signs of the Zodiac are generally also credited to the Babylonians and said by modern scholars to have come to India via a Greek influence after the time of Alexander (300 BCE). However, the Vedic 360 wheel of heaven is also said to be divided into twelve parts. Whether these twelve parts are identical with those of the western signs of the Zodiac is not clear from the Vedas themselves, but it is clear that the idea that the 360 part Zodiac could be divided into twelve is also there. In RV 1:164:11, the Sun wheel in heaven is said to have 12 spokes, and to be subdivided into 360 pairs of "sons": the days (consisting of day and night), rounded off to an arithmetically manageable number, also the basis of the "Babylonian" division of the circle in 3600.

The division in 12 already suggests the Zodiac, and we also find, in the footsteps of NR. Waradpande, that a number of the Zodiacal constellations/ Rāśi राशि (classically conceived as combinations of 2 or 3 successive lunar mansions or Nakṣatras of 13˚ and 20’ each) are mentioned. Obviously the RV should be dated prior to the beginning of Kaliyuga, as we have already demonstrated and hence the Babylonian origin of the twelve sign Zodiac is suspect.

WHEN AND WHERE WERE THE 12 SIGNS OF THE ZODIAC (RĀŚI) FIRST MENTIONED

The 12 signs of the Zodiac with Sanskrit names are mentioned in the Brihat Saṃhitā and Laghu Bhāskarīyam. The former is the work of Varāhamihīra (see chapter 11 for dating). He is supposed to have borrowed it from a Greek of the 4th century BCE (could it be Hipparchus?). The whole theory of India borrowing from the Greeks needs to be re-examined in greater detail and with a great deal more precision than has been the case till now, since it is now clear that the methods used by the Indics were quite unique and distinct from those used by the Greeks needs to be re-examined in greater detail and with a great deal more precision than has been the case till now, since it is now clear that the methods used by the Indics were quite unique and distinct from those used by the Greeks. Further Yajnavalkya, who lived at least a millennia before Meton and the Metonic cycle of 19 years, is credited with discovering that it takes 95 years to synchronize the motions of the Sun and the Moon. The Indic tradition moreover is a living tradition which is practiced by Jyotish even till today.

TABLE 9 THE NAMES OF THE ZODIAC IN DIFFERENT LANGUAGES

no.	symbol	Long.	Latin name	English translation	Greek name	Sanskrit name	Sumero-Babylonian name
1	□	0°	Aries	The Ram	Κριός	Meṣa	MUL LUḪUN.GA "The Agrarian Worker", Dumuzil
2	□	30°	Taurus	The Bull	Ταῦρος	Vṛṣabha	MULGU$_4$.AN.NA "The Steer of Heaven"
3	□	60°	Gemini	The Twins	Δίδυμοι	Mithuna	MULMAŠ.TAB.BA.GAL.GAL "The Great Twins" (Lugalgirra and

							Meslamta-ea)
4		90°	Cancer	The Crab	Καρκῖνος	Karka	MULAL.LUL "The Crayfish"
5		120°	Leo	The Lion	Λέων	Siṃha	MULUR.GU.LA "The Lion"
6		150°	Virgo	The Virgin	Παρθένος	Kanyā	MULAB.SIN "The Furrow"; "The Furrow, the goddess Shala's ear of corn"
7		180°	Libra	The Scales	Ζυγός	Tula	*zibanitum* "The Scales"
8		210°	Scorpio	The Scorpion	Σκορπίος	Vṛścika	MULGIR.TAB "The Scorpion"
9		240°	Sagittarius	Centaur The Archer	Τοξότης	Dhanus	MULPA.BIL.SAG, *Nedu* "soldier"
10		270°	Capricorn	"Goat-horned" (The Sea-Goat)	Αἰγόκερως	Makara	MULSUḪUR.MAŠ "The Goat-Fish"
11		300°	Aquarius	The Water Bearer	Ὑδροχόος	Kumbha	MULGU.LA "The Great One", later *qâ* "pitcher"
12		330°	Pisces	The Fishes	Ἰχθεῖς	Mīna	MULSIM.MAḪ "The Tail of the Swallow", later DU.NU.NU "fish-cord"

Surely such an observation would have been preceded by extensive data collection and the ability to manipulate large numbers mathematically and the ability to use a written script. There is ample evidence that the Śatapatha Brāhmaṇa and the Bṛhadāranyaka Upanishad (which forms the last 6 chapters of the Śatapatha Brāhmaṇa) both of which are credited to Yājnavalkya, and which contain significant amount of astronomical observations predate the advent of the Greeks and most likely even the Babylonians.

There is an excellent discussion of the Age of the RV by Dr. Narendra Nath Law[136] describing the entire debate between Whitney, and Thibaut on the one hand and Jacobi and Tilak on the other which encapsulates in 167 pages the refutation of the objections raised by the Naysayers (Whitney, Biot, Max Müller and many others). I do not wish to repeat the arguments, as it behooves the patient investigator to ferret out these facts themselves

[136] *Law, Narendra Nath "The Age of the RV*

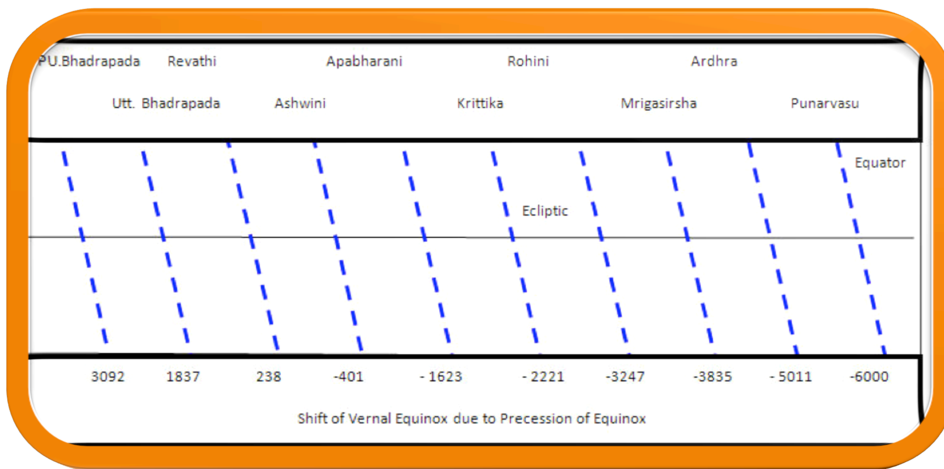


FIGURE 3 THE SHIFT OF THE VERNAL EQUINOX THROUGH DIFFERENT NAKṢATRA'S OVER 6 MILLENNIA

The following analysis of the Vedic calendar is attributed to Glen R Smith

THREE MEAN MOTIONS OF THE SUN [137]

The three mean motions of the Sun used to construct the Cosmological Time Cycles shown above are as follows:

ONE SIDEREAL YEAR = 360 sidereal days + 6 sidereal days + 0.2563795 sidereal days= 366.2563795 sidereal days.

Remember we are not talking about civil solar days here; we are talking about the total number of times the Earth rotates on its axis in relation to a single star during the course of one year. This happens to be one greater than the mean solar days in a year which is…

ONE SIDEREAL YEAR = 365.2563631 MEAN SOLAR DAYS

These three mean motions of the Sun may be compared to the hour, minute and second hands of a clock. Each cycle is counted and completed separately. Using this system of the three mean motions, the ancient's reckoned time that put the day, year, and longer periods of time into exact correspondence with each other.

THE USE OF THE SEXAGESIMAL NUMBER SYSTEM IN THE VEDIC ERA

The first two mean solar motions, that of 360 + 6 Earth revolutions generate the sexagesimal number system completely. A count of six for every 360 is the same as one for every 60. This is the basis of the six seasons of the year observed by the Hindus. Counting six days per year, the second mean motion of the Sun completes a cycle of 360, the number of degrees in a circle, after 60 years which correlates with the Babylonian Sossos period and the cycles of Jupiter and Saturn.

[137] *Glen R. Smith The Six Thousand Year Barrier, An Essay on Hindu Astrology, see also*

TABLE 10: THE STRUCTURE OF THE BABYLONIAN SOSSOS PERIOD.

Year	First mean motion	Second mean motion	Total
1	360	6	366
2	720	12	732
3	1080	18	1098
4	1440	24	1464
5	1800	30	1830
10	3600	60	3660
(sossos) 60	21,600	360	21,960
(neros) 600	216,000	3600	219,600
(saros) 3600	1,296,000	21,600	1,317,600

In the same interval that the first mean motion completes a count of 21600 it has done so at a rate 60 times greater than the second mean motion 360 × 60 and represents the number of arc minutes in a circle. The number 21600 is also the same average number of breaths (prana) a person will make in a 24 hour period.

EVIDENCE OF USE OF THE SIDEREAL YEAR IN THE VEDIC ERA

The RV the earliest of the Hindu scriptures says the following: Twelve spokes, one wheel, and navels three. Who can comprehend this? On it are placed together three hundred and sixty like pegs. They shake not in the least. (Dīrghatamas, RV, 1.164.48) see Chapter 3, Basic Features of the Vedic Calendar.

A seven-named horse does draw this three-naved wheel… Seven steeds draw the seven-wheeled chariot… Wise poets have spun a seven-strand tale around this heavenly calf, the Sun. (Dīrghatamas, RV 1.164.1-5)

The number seven related to the Sun has much significance when understanding the third mean solar motion (0.2563795). The Kali-yuga of 432,000 years is the unit of reference for determining the length of the sidereal year in Hindu cosmological time cycles. During the course of 10,000 years there are seven rotations of the third mean solar motion. For a single year the count is 0.2563795 diurnal revolutions of the earth. For two years it is .512759 and so on. One complete rotation (to equal 366.2564…) of the third motion takes 1428.571429 sidereal years. Or you can reduce it to a fraction of $1428\frac{4}{7}$ sidereal years.
(366.2563795…)/ (0.2563795…) = 10000/7= $1428\frac{4}{7}$ sidereal years

The integer of this sidereal interval, 1428 years, multiplied by the number of years in a Kali-yuga and then further multiplied by seven equals the number of years of fourteen Manus. (See table 4).

1428 × 432,000 × 7 = 4,318,272,000 = 14 manus
The fractional part of this sidereal interval, $\frac{4}{7}$ years, multiplied by seven and further multiplied by the number of years in a Kali-yuga equals the time of an introductory dawn (see table 4).

$^{4}/_{7} \times 7 \times 432{,}000 = 1{,}728{,}000$ years = introductory dawn.

Relating the Vedic verses above to what we have just demonstrated it is clear that the "navels three" refer to the three mean motions of the Sun and "seven-wheeled chariot" to the rate of precession of the equinoxes. Thus, there can be no doubt that the cosmological time cycles were already an established conclusion at the time of the Vedic era and not in the formative stages.

THE VEDAṆGA JYOTIṢHA

The Vedāṅgas are considered to be prerequisite reading, and form the basis of the presuppositions (Arthāpatti) without which it would be difficult to make sense of the Veda. The earliest available written text on astronomy, Vedāṅga Jyotiṣa is found in two Recensions: the RV Jyotiṣa and the YV Jyotiṣa. **The Vedāṅga Jyotiṣa**, (VJ) is an Indian text on Jyotiṣa (Indian astronomy), redacted at a later date, by **Lagadha** (लगध). The text is foundational to the Jyotiṣa discipline of Vedāṅga and the Veda, and is dated to the middle of the 2nd Millennium BCE. We are fairly certain that this is a text of great antiquity. The text contains more than one astronomical event that can be reproduced by planetarium software. The text describes rules for tracking the motions of the Sun and the Moon. In the VJ Lagadha praises astronomy as the crowning subject in the ancillary Vedic studies. The quote is cited at the end of the chapter. The Vedāṅga Jyotiṣa[138] is available in three Recensions: those of YV, RV, and AV, which contain many similar passages but exhibit marked differences as well.[139]
The creator of the VJ Calendar was Lagadha, who has been located in present day Kashmir. RV Recension comprises exactly 35 verses and the YV version comprises 43 verses. The AV version deals more with astrology and appears to have been composed at later time.

THE CALENDAR DURING VEDĀṄGA JYOTIṠA ERA

Some investigators (Holay) feel that the RV VJ is based on a 19 year cycle, whereas the YV VJ is the classical 5 year Yuga version. This hypothesis has been challenged by Abhyankar[140]. It commences on Ṡukla Pratipada, in the month of Magha, when the Sun and the Moon are together in Sravishta later called Dhanishta and when the Uttarāyana (Winter Solstice) takes place.

TABLE 11 THE CALENDAR DURING VEDĀṄGA JYOTIṠA ERA
Number of Years in a cycle 5
Number of Solar days = 1800
Number of Sāvaṇa or civil days 5*366 = 1830 days. Thus there are 366 Sāvana days in a year.

[138] *Vedanga Jyotisha, English translation: T.S. Kupanna Sastry, Indian National Science Academy, Bahadurshah Zafar Marg, New Delhi. Hindi translation: Girja Shankar Shastri, Jyotiṣa Karmakanda and Aadhyātma Shodh Sansthan, 455 Vasuki Khurd, Daraganj, Allahabad-6.*
[139] *op cit*
[140] *Abhyankar, KD., 5 Year Yuga in the* VEDĀṄGA JYOTIŚA, IJHS, VOL. 39.2, 2004,227-230

Number of Solar months = 60
Number of Lunar synodic months = 1830/29.53059= 61.96963894
There are 29.53059*62 = 1830.8965[d]
Number of Lunar sidereal months = 1830/27.3 = 67
Number of intercalary Lunar months 62-60 = 2
Tithis (Lunar days) = 62*30 = 1860 or 372 Tithis per year
Number of omitted or Kshaya Tithis = 1860-1830 = 30
Number of Nakṣatra days 67*27 = 1809.
1 day = 30 Muhurta = 60 Nadikas, 1 Muhurta = 48 minutes =2 Nadikas = 20.1 Kalas
A day had to be added after 5 years since 62*29.53059= 1830.8965 and to keep it consistent the addition of a day had to be omitted every 10th yuga'
Furthermore the phases of the Moon would continuously change with reference to the calendar days. So there had to be a correction for that
For The Case Of The 19 Year Cycle
Number of years in a cycle= 19
Number of Sāvaṇa or civil days 19*366 = 6954 days
Number of sidereal days = 0.9972696246 *6954 = 6935
Number of Solar months = 228 =19*12
Number of Lunar synodic months = 6954/29.53059= 235.48
Number of Lunar sidereal month = 6935/27.3 = 254.03
Number of intercalary Lunar months 235-228 = 7
Total days = 6954 +7 *29.53059 =7161 civil days =
Tithis (Lunar days) = 235*30 =7050
Number of omitted or Kshaya Tithis = 7161-7050 = 111
Total number of Lunar months = 19*12+7 = 235
Number of Nakṣatra days 6935
Number of years in a cycle= 95, the exact number of intercalary months is 35
For 19 yugas, in VJ there are 2*19 = 38 intercalary months
Lunar synodic months = 62*19 = 1178
Number of Sāvana days 1178*29.53 = 346786.34
In the VJ this would be 34770 (366*95)
The number of Solar days 365.2563*95 = 34699.3485 The difference is 87 days, 87/29.53= 2.94 synodic months that must be dropped

TABLE 12 THE MEASURES OF TIME USED IN VJ ARE AS GIVEN BELOW
1 Lunar Year = 360 Tithis
1 solar year = 360 solar days
1 civil day = 30 muhurtas

1 muhurta = 2 nadikas = 20.1 kalās = 48 minutes
1 day (aho-rātra, day[141] and night) = 30 muhurtas = 1 Nychthemeron
Nadika = 10 $\frac{1}{20}$ kalās = 10.05 kalas
1 day = 124 amsas, 1 day -= 603 kalas = 60 nadikas = 30 muhurtas.
1 kalā = 124 Kāşţhās
1 Chandramāsa = 2 parvans (angular measure) = is equivalent to 2 Pakṣas

The Retrodicted Nakṣatra Event Table (RNET) (using VOYAGER software, see Table 2 in Chapter VI) gives us a date 0f 1861 BCE for this, making the assumption that Dhanishta is δ Capricornus. *If Dhanishta is assumed to be β **Delphini** we obtain 1357 BCE as the date for the VJ. This is one of the few instances in which the ambiguity in the identity of the Nakṣatra affects an important date. But even in this instance we did not come away empty handed and were able to come up with reasonable bounds on the value.

2 fortnights = 30 tithis. Why did they use a time division of the day into 603 kalas? Because in a yuga there are 1830 Sāvana days and 1809 Nakṣatra transits (sidereal days) Thus the moon travels through 1 Nakṣatra in 610 kala or **1809 ×1$\frac{7}{603}$ = 1830 (civil or sāvana) days**. Or the moon travels through 1 Nakṣatra in 610 kalas. It is to be noted that 603 is divisible by 67, the number of sidereal months. The further division of a kala into 124 Kāşţhās was in symmetry with the divisions of the Yuga into 62 synodic months or 124 fortnights (of 15 Tithis) or parvans. A parvan is the angular distance traveled by the Sun from a full moon to a new moon or vice versa. The Sun stays in each asterism $\frac{366}{27} = 13\ \frac{5}{9}$ days. The number of risings of the asterism Sravishtas (Dhanishta) in the Yuga is the number of days plus 5 (1830 + 5= 1835). The number of risings of the moon is the days minus 62 (1830 – 62) = 1768.

There are 360 Tithis in a lunar year (29.53*12 = 354.36 days). This is short of the solar year by 10.89 days. With reasonable accuracy, we can intercalate 7 intercalary months in 19 years (19*12 +7 =) 235 lunar months. Additional 7 months form 210 Tithis (7*30). Thus there is a difference of 210/19 = 11 and 1/19 Tithis (10.89 days) between a solar and a lunar year. Thus a **solar year consists of 371 and 1/19 Tithis**. To summarize,

1 lunar year = 360 Tithis = (29.53*12) = 354.36 days = 1 solar year – 10.89 days

We intercalate 7 intercalary months or 210 Tithis in 19 years. The difference between 1 solar year and 1 lunar year is 210/19 = 11 and 1/19 Tithis = 10.89 days. On the average a 1 Tithi is 0.9852857143 civil days =$\frac{(12\times synodic\ month)}{360}$

TAKŚAŞĪLA IS AN EXCELLENT CANDIDATE FOR THE PLACE WHERE LAGADHA MADE HIS OBSERVATIONS.

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[141] *The word day is used ambiguously meaning a day and a night of 24 hours, as well as the part of the day between sunrise and sunset. We will use the term civil day to denote a complete day of 24 hours or a Nychthemeron. Nychthemeron or nycthemeron (Greek νυχθήμερον from the words* nykt- *"night", and* (h) emera *"day, daytime") is a period of 24 consecutive hours. It is sometimes used, especially in technical literature, to avoid the ambiguity inherent in the term day.*

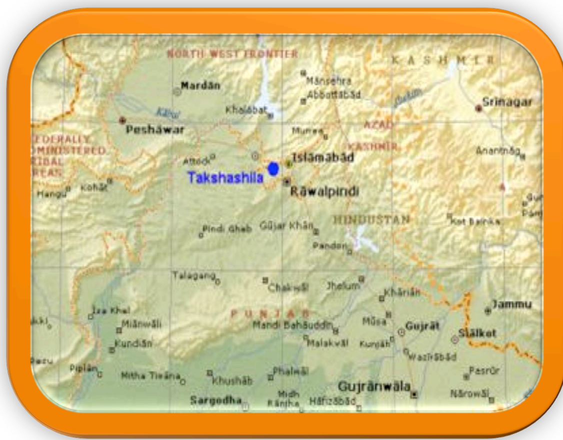


FIGURE 4 TAKŚAŞĪLA LATITUDE COMPATIBLE WITH ANCIENT ERA LATITUDE MEASUREMENT

It was observed at the location where Lagadha resided that the difference between the shortest day at the winter solstice and the longest day at the summer solstice was 6 muhurtas or 4 hours. When we solve for the daylight hours during the longest and the shortest days, we get 18 muhurtas($14^h 24^m$) and 12 muhurtas (9^h 36^m) respectively, or the ratio of the longest day to the shortest day = $\frac{14.4}{9.6} = \frac{3}{2}$. The same quantities for half a day are 7.2^h 4.8^h, each of which differs from the mean value of 6^h by $1.2^{h.}$ This quantity is known as the **ascensional difference** (AD). It can be shown that, Sin (AD) = Tan ϕ Tan δ, where AD = $1.2(15^o) = 18^o$, since $1^h = 15^o$ of arc. The latitude ϕ can be determined to be 35^o as the Sun's maximum declination was 23^o 53', assumed to be 24^o by the ancient Indic.

As we can see the entire methodology is quite unique to India and does not find a parallel anywhere else and yet Pingree decided to latch on to the ratio of $\frac{3}{2}$ for the daylight hours during the longest day versus the daylight hours in the shortest day, and immediately concluded that the Indics had plagiarized their entire methodology from Babylon, since the Babylonians had also come up with the same ratio. There are 2 things wrong with this logic.

Computational astronomy did not begin in Babylon till after Nebuchadnezzar in the eighth century BCE.

The ratio $\frac{3}{2}$ is valid for all locations at latitude of 35^o regardless of longitude. Pingree's assumption that there no locations in India which are at 35^o overlooks the fact that in ancient India, the Indic civilization extended from Afghanistan, well into Central Asia. It is quite possible that Lagadha did his studies while at Taksashila (present day Pakistan, latitude and made his observations in the hills north of Taksashila. In fact for Srinagar the capital of Kashmir state which is at 34^o N latitude this ratio turns out to be very close to 1.5 (approximately 1.41).In any event, Lagadha could have made his observations anywhere near Leh or Baramula or north of Taksashila.

Whereas we believe based on astronomical dating that the VJ was composed at a date with a terminus ante quem 1350 BCE, the occidental has been very dismissive of the VJ right from the outset, because conceding that the VJ was a valuable piece of literature and that it represents an advance over what existed previously, would be to admit that the antiquity of the Indic contribution predated Greece and Babylon. The primary criticism has been that the five year Yuga system and the associated scheme of Adhikamāsas are very crude and do not attest to a strong tradition in astronomy especially

observational astronomy. It is the strongly held belief of most informed historians of this tradition, especially Prof Narahari Achar, who has published extensively in the area of Dating of the ancient texts, that the VJ calendar is intimately connected with the Vedic ritual yagna. Contrary to the facile conclusions drawn by western Indologists, there is sufficient evidence to suggest that the Vedic astronomers not only had a tradition of observation, but were also aware of the shortcomings of the five year Yuga period. In any event, we are not aware of any manuscript anywhere in the IE universe dating back to that period, which lays out in such detail, an algorithm for composing the calendar.

In fact, the Indic was clearly closer to the ethos of the modern computational scientist than was Ptolemy in that he provided a step by step procedure which we call today the algorithm and the expressions we use today would be easily recognizable by him while the same cannot be said of the Greek astronomers.

Vedāńga Jyotiśa has this to say about Mathematics, sloka 35:

Yathā Śikha mayūrāṇām nāgānām maṇayo yatha ǀ

Tathā vedāṇga ṣāstrāṇām jyotiṣam mūrdhani sthitam ||

यथा शिखा मयूराणां नगानां मणयो यथा ।

तथा वेदाड्ग शास्त्राणां ज्योतिषं मूर्धनि स्थितम् ।।35

“Just as the feathers of a peacock and the jewel-stone of a snake are placed at the highest point of the body (at the forehead), similarly, the position of Jyotiṣa is the highest amongst all branches of the Vedas and the Śāstra.”

CHAPTER IV
HISTORICAL PERSPECTIVES PART II
JAINA ASTRONOMY AND THE SIDDHĀNTIC ERA

JAINA ASTRONOMY

The major work here is the Sūryaprajnāpati (SP) or the Sūryapannati. The dating of SP is indicated by the statement that Dakṣiṇāyana was heralded in the Puṣya Nakṣatra, which would indicate a date of 760 BCE. Sūrya Prajnāpati Sūtra is highly revered text in Jainism. The teaching and principles contained in it is followed by the Shwetambar sect. The principal source of information is Malaygiri's commentary, Sūryaprajnāpati vrtti. Bhadrabāhu appears to be the author of the SP. It follows the subject matter of the Yajusha and Artha Jyotiṣa , in following a five year lunisolar cycle.

This text is a part of the Jain canonical literature called Upang Agamas, which provides explanation to the thoughts exerted by the primary text called Agama Sūtras. Sūrya Prajnāpati Sūtra deals with the heavenly bodies like the Sun and planets. It contains a detailed description of each of these celestial objects. There is also a comprehensive approach to the mathematics involved in calculating the motions of the planets and the Sun.

Jainism was a religion and philosophy founded by Mahāvira. At this time the evidence seems to indicate that he was born much later than Gautama Buddha the founder of the Baudhik System of beliefs. Followers of these religions played an important role in the future development of India. Jaina mathematicians were particularly important in bridging the gap between earlier Indian mathematics and the 'Classical period', which was heralded by the work of *Āryabhaţa.* Regrettably there are few extant Jaina works, but in the limited material that exists, an incredible level of originality is demonstrated. Perhaps the most historically important Jaina contribution to mathematics as a subject is the progression of the subject from purely practical or liturgical requirements. During the Jaina period, mathematics became an abstract discipline to be cultivated "for its own sake".
The important developments of the Jainas include:

- The theory of numbers.
- The binomial theorem.
- Their fascination with the enumeration of very large numbers and infinity.
- All numbers were classified into three sets: enumerable, innumerable, and infinite.
- Five different types of infinity are recognized in Jaina works: infinite in one and two directions, infinite in area, infinite everywhere, and infinite perpetually. This theory was not realized in Europe until the late 19th century (usually attributed to George Cantor).
- Notations for squares, cubes and other exponents of numbers.
- Giving shape *to Bīja Gaṇita samikaran* (algebraic equations)
- Using the word *Ṣunya meaning void to refer to zero. This word eventually became zero after a series of translations and* transliterations. (See Zero: Etymology.)

Jaina works also contained:

- The fundamental laws of indices
- Arithmetical operations
- Geometry
- Operations with fractions
- Simple equations

- Cubic equations
- Quartic equations (the Jaina contribution to algebra has been severely neglected)
- Formula for π (root 10, comes up almost inadvertently in a problem about infinity)
- Operations with logarithms (to base 2)
- Sequences and progressions

Finally, of significant interest is the appearance of Permutations and Combinations in Jaina works, which was used in the formation of a Pascal triangle, called *Meru-prastara*, used a few centuries after Hindu mathematician Pingala but many centuries before Pascal 'invented' it.

SŪRYA PRAJNĀPATI

Sūrya Prajnāpati is a mathematical and astronomical text which:

- Classifies all numbers into three sets: enumerable, innumerable, and infinite.
- Recognizes five different types of infinity: infinite in one and two directions, infinite in area, infinite everywhere, and infinite perpetually
- Measures the length of the lunar month (the orbital period of the Moon around the Earth) as **29.5161290^d**, which is only 20 minutes longer than the modern measurement of **29.5305888^d**

We see a high degree of sophistication in the mathematical techniques used in the SP which bridges the gap between VJ and the Siddhāntic period.

THE SIDDHĀNTIC PERIOD

The Siddhāntic period is characterized by standardization of techniques and the increasing sophistication of mathematical algorithms used. The Occidental has characterized this period as a medieval period, in analogy to the medieval period (in a pejorative sense) in Europe the duration of which is supposed to have carried on from about 400 CE till the discovery of the new world in the end of the 15th century. The use of the word medieval in the Indian context is not appropriate since many of the debilitating social conditions and the extreme poverty that was prevalent in Europe during those years did not exist in India. Considering the longer time frames of Indian history, it is more appropriate to refer to the entire Common Era Anno Domini as the Modern era of Indian astronomy.

SŪRYA SIDDHĀNTA सूर्यसिद्धान्त

The Sūrya Siddhānta is a treatise of Indian astronomy that is attributed to an individual called Maya Asura or Asura Maya. It is considered the Canonical example of the astronomic literature during the Siddhāntic era. Later Indian Mathematicians and Astronomers such as Āryabhaţa and Varāhamihīra appear to have known of this text and have made references to it. Varāhamihīra in his Panchasiddhāntika contrasts it with four other treatises, besides the Paitamaha Siddhāntas (which is more similar to the "classical" Vedāńga), the Paulisa and Romaka Siddhāntas) and the Vaśişţa Siddhānta. He regards, the Sūrya Siddhānta as the most accurate as well as the most authoritative. There were in fact 18 Siddhāntas that were reputedly composed but out of the eighteen only the above named 5 have survived even into the era of Siddhantic Astronomy. The names of the Siddhāntic texts are Sūrya, Brahma, Vyāsa, Vaśişţa, Atri, Parasara, Kasyapa, Nārada, Gārga, Marici, Manu, Angirasa, Lomasa, Pulisa, Cyavana, Yavana, Bhrgu, Saunaka, or Soma.

The work referred to by the title Sūrya Siddhānta has had more than one edition, over the centuries. There may have been an early work under that title dating back to the Buddhist Age of India. The work as preserved and subsequently translated by Burgess [142](1858) dates to the first millennium CE. Utpala, a 10th century commentator of Varāhamihīra, quotes six slokas of the Sūrya Siddhānta of his day, not one of which is to be found in the text now known as the Sūrya Siddhānta. The present Sūrya Siddhānta may nevertheless be considered a direct descendant of the text available to *Varāhamihīra* and has not changed appreciably.[143] This article discusses the text as edited by Burgess. For what evidence we have of the Gupta period text, see Pancha-Siddhāntika. Whenever we are referring to the specific Siddhānta will refer to it by its proper name and Recension namely SSV (for Sūrya Siddhānta *Varāhamihīra* edition), which has a date corresponding to the period when he flourished.

"*It has rules laid down to determine the true motions of the luminaries, which conform to their actual positions in the sky. It gives the locations of several stars other than the Lunar Nakṣatras and treats the calculation of solar elipses. From a standpoint of historiography, the Sūrya Siddhānta is an important text, since it gives a wealth of data from which one can decipher the probable age of the document.*"[144].

Regarding the extent to which the Indics were beholden to the Greeks, Ebenezer Burgess is quite emphatic, that there did not appear to be any such dependence, even though he is careful not to grant the Indics a higher antiquity. Quote from Ebenezer Burgess on the Originality of Hindu Astronomy.

"The date of the scientific Hindu astronomy is indeed 421 years elapsed of the Śaka or 499 CE, the time of Āryabhaţa I, but we can show it is not a wholesale borrowing either from the Babylonian or the Greek science…. It will appear from the above presentation that the Hindu values of the astronomical constants are almost all different from their Greek values. Hence both the systems must be independent of each other.... It must be said to the credit of Hindu astronomers that they determined all the constants anew.... I have established that the Hindu astronomers were in no way indebted to the Greeks in this part of the subject; the methods of the former were indeed of the most elementary (how so? merely by asserting it to be so, does not make it a reality. Ptolemy could not write an algebraic expression); yet the Hindu astronomers could solve some problems where Ptolemy failed..." We thus come to the conclusion

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142 Ebenezer Burgess, "Translation of the Sūrya-Siddhānta, a text-book of Hindu Astronomy", Journal of the American Oriental Society 6 (1860): 141–498. Republished by Motilal Banarsidass , Edited by Phanindralal Ganguly and an introduction by Prabhod Chandra Sengupta

143 Romesh Chunder Dutt, A History of the Civilization in Ancient India, based on Sanscrit Literature, vol. 3, ISBN 0543929396 p. 208.

144 Bibliography to Chapter VI" 'As a summary of Hindu science should be quoted the chapter on science by W.E. Clark in "The Legacy of India" (edited by G.T. Garratt, Oxford 1937). A detailed summary of the literature up to 1899 is given by G. Thibaut in his article "Astronomie, Astrologie und Mathematik" in vol. III, 9 of the "Grundriss der Indo-Arischen Philologie und Altertumskunde". Very useful is James Burgess, Notes on Hindu Astronomy and the History of our Knowledge of It (J. of the Royal Asiatic Soc. of Great Britain and Ireland, 1893, p. 717-761) where one finds complete references to the early literature which contains much important information which is no longer available otherwise.

The translation by E. Burgess [Ebenezer Burgess 1805 - 1870] of the Sūrya Siddhānta, quoted below p. 186, contains extensive commentaries which must be read by any serious student of this subject. For the "linear methods" in Hindu astronomy cf. the references to Le Gentil and Warren on p. 186. For the form which the Greek theory of epicyclic motion of the planets took in India and then in al-Khwarizmi, see O. Neugebauer, The transmission of planetary theories in ancient and medieval astronomy, Scripta Mathematica, New York, 1956.

E.S. Kennedy, A survey of Islamic astronomical tables, Trans. Amer. Philos. Soc., N.S. 46 (1956) p. 123-177 is a publication which shows the great wealth of material still available but barely utilized for the investigation of medieval astronomy, its Greek, Islamic and Hindu sources and their interaction.'

that although the scientific Hindu astronomy is dated much later than the time of Ptolemy, barring the mere idea of an epicyclic theory from outside, its constants and methods are all original. Even as to the idea, the term Sighra (the apex of quick motion) which has been wrongly translated by the word 'conjunction,' shows that the Hindu angle of vision was quite different from the Greek, while the idea of the gods of 'Manda' and Sighra, presents a phase of growth of the science before the epicyclic theory came into being, be the idea Hindu or Babylonian.

"*In discussing the originality of Hindu astronomy we have purposely avoided the Sūrya Siddhānta, because no definite date can be assigned to the work, its latest development taking place about 1100 CE. Yet the modern Sūrya Siddhānta is a complete book on Hindu astronomy and at the same time an attractive book too. No student of Hindu astronomy (why not admit that that this statement is* ***equally*** *applicable to the history of all astronomy and not just Hindu astronomy) would be deemed well equipped for research without thoroughly studying it and Burgess's translation, indeed, gives a very clear and complete exposition and discussion of every rule that it contains together with illustrations also. Besides his [Ebenezer Burgess] views about the originality of Hindu astronomy are the sanest and still substantially correct.* ["* Pp. 387-92" [see 1057-1062]] This translation is indispensable to any researcher also for the wealth of references contained in it. It is indeed a real monument to his own memory left by the late Reverend E. Burgess himself." P.C. Sengupta*

TABLE 1 TABLE OF CONTENTS OF SŪRYA SIDDHĀNTA	
Sūrya Siddhāntic Time-Cycles and Age of Universe	
The Mean Motions of the Planets	The True Places of the Planets
Mandaphala Equations (equations of centre)	Sighraphala equations
Three questions - Direction, Place and Time	The Eclipse of the Sun
The Eclipse of the Moon	The Projection of Eclipses
Planetary Conjunctions and Stars	Certain Malignant Aspects of the Sun and Moon
Heliacal Risings and Settings of Planets.	The Moon's Risings and Settings.
Cosmogony, Geography, Dimensions of Creation.	The Gnomon
Movement of the Heavens and Human Activity	Limits of Space and Time: inferences from Sūrya Siddhānta

Kathy Deutscher 5/23/2014 2:07 PM
Comment [2]:

Methods for accurately calculating the shadow cast by a gnomon are discussed in both Chapters 3 and 13.

EXCERPTS FROM THE SŪRYA SIDDHĀNTA

ASTRONOMICAL TIME CYCLES

The astronomical time cycles contained in the text were remarkably accurate at the time. The Hindu Time Cycles , copied from an earlier work, are described in verses 10–23 of Chapter 1:

10. The time which destroys is the real time, and the other kind of time is for the purpose of computations. They are of two kinds, the gross one is used for real time use and the firm one for the purpose of computations.
11. That which begins with respirations (prana) is called real.... Six respirations make a vinadi, sixty of these a nadi;
12. And sixty nadis make a sidereal day and night. Of thirty of these sidereal days is composed a month; a civil (Sāvana) month consists of as many sunrises;
13. A Lunar month, of as many Lunar days (Tithi); a Solar (saura) month is determined by the entrance of the Sun into a sign of the Zodiac; twelve months make a year. This is called a day of the gods.
14. The day and night of the gods and of the demons are mutually opposed to one another. Six times sixty of them are a year of the gods, and likewise of the demons.
15. Twelve thousand of these divine years are denominated a Chaturyuga; of ten thousand times four hundred and thirty-two Solar years
16. Is composed that Chaturyuga, with its dawn and twilight. The difference of the Krtayuga and the other yugas, as measured by the difference in the number of the feet of Virtue in each, is as follows:
17. The tenth part of a Chaturyuga, multiplied successively by four, three, two, and one, gives the length of the krita and the other yugas: the sixth part of each belongs to its dawn and twilight.
18. One and seventy Chaturyuga make a Manu; at its end is a twilight which has the number of years of a Krtayuga, and which is a deluge.
19. In a kalpa are reckoned fourteen Manus with their respective twilights; at the commencement of the kalpa is a fifteenth dawn, having the length of a Kritayuga.
20. The kalpa, thus composed of a thousand Chaturyuga, and which brings about the destruction of all that exists, is a day of Brahma; his night is of the same length.
21. His extreme age is a hundred, according to this valuation of a day and a night. The half of his life is past; of the remainder, this is the first kalpa.
22. And of this kalpa, six Manus are past, with their respective twilights; and of the Manu son of Vivasvant, twenty-seven Chaturyuga are past;
23. Of the present, the twenty-eighth, Chaturyuga, this Kritayuga is past....

When computed, this astronomical time cycle would give the following results:
The average length of the tropical year as 365.2421756^d, which is only 1.4 seconds shorter than the modern value of 365.2421904^d (J2000). This estimate remained the most accurate approximation for the length of the tropical year anywhere in the world for at least another six centuries, until Muslim mathematician Omar Khayyam (see table 6, chapter VIII))gave a better approximation, though it still remains more accurate than the value given by the modern Gregorian calendar currently in use around the world, which gives the average length of the year as 365.2425^d.

The average length of the sidereal year, the actual length of the Earth's revolution around the Sun, as **365.2563627^d**, which is virtually the same as the modern value of **365.25636305^d** (J2000). This remained the most accurate estimate for the length of the sidereal year anywhere in the world for over a thousand years. The actual astronomical value stated for the sidereal year however, is not as accurate. The length of the sidereal year is stated to be **365.258756^d**, which is longer than the modern value by 3 minutes 27 seconds. This is due to the text using a different method for actual astronomical computation, rather than the Hindu cosmological time cycles copied from an earlier text, probably because the author didn't understand how to compute the complex time cycles. The author instead employed a mean motion for the Sun and a constant of precession inferior to that used in the Hindu cosmological time cycles.

ON THE YUGAS

We have maintained that the possible explanation for the large numbers that the Indics came up with, is a consequence of their choosing a LCM for all the possible cycles that could occur, during that period. But there is a dissenting voice to such a conclusion, and we include that in order to indicate that we remain agnostic on the issue and that further work needs to be done to solve the riddle of the Mahāyuga.

R. R. Karnik[145] observes "In fact no number however large can give an integer multiple of the number of years required. The answer is simple and elementary. The least count used in Sūrya Siddhānta for general computations is one Kala or minute of the arc of which there are 21,600 in the whole circle. If one has to specify the movement of planetary element to the accuracy of one Kala in a year a period of 21,600^y will have to be taken. This is the period of a Mahāyuga and its tenth part which is 2,160^y is the period of Kaliyuga. Dwaparyuga is twice this or 4,320^y, Tretayuga is thrice this or 6,480^y and Kṛtayuga is four times this or 8,640^y, all four totaling up to 21,600^y. The accuracy of one Kala in a year is not adequate. To therefore obtain an accuracy of one two-hundredth of a Kala in a year, a period that is two hundred times 21,600 or 4,320,000 years is necessary. The first number of 21,600 years is the real time and the other number of 4,320,000 years taken for Mahāyuga is the frame time or the non-real time. The Sūrya Siddhānta records in i.10.

1.10a lokānām antakṛt kālah kālonyah kalanātmakah

1.10b sa dvidhā sthūlasūkśmatvān mūrtaś chāmūrta uchyate

१.१०क लोकानाम् अन्तकृत् कालः कालो +अन्यः कलनात्मकः /

१.१०ख स द्विधा स्थूलसूक्ष्मत्वान् मूर्तश् चामूर्त उच्यते //

Rendered in English it means:

"The time which destroys is the real time, and the other kind of time is for the purpose of computations. They are of two kinds, the gross one is used for real time use and the firm one for the purpose of computations."

For the movement of the apogee of the sun this time frame of 4,320,000 years is not adequate and a number thousand times this is required which is 4,320,000,000 years called Kalpa. This is given in the Sūrya Siddhānta i.20, thus,

ittham yuga sehesrena bhutasanharakarkah/

kaIpo brahmam ahah proktam sarvari tasya tavati//

"Such thousand yugas, of the all destroying kind, are called a day or Kalpa of Brahma the night being of equal duration."

१.२०क इत्थम् युगसहस्रेण भूतसम्हारकारकः /

१.२०ख कल्पो ब्राह्मम् अहः प्रोक्तम् शर्वरी तस्य तावती //

The Sūrya Siddhānta gives the rates of motions of apogees and nodes starting from i.41. It starts with the apogee of the sun which rate is given by:

"Prāggate Sūrya mandasya kalpe saptāṣtavahnayaha"

The apogee (mandocca) of sun goes eastwards 387 (bhagana) in a Kalpa.

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[145] http://www.hindunet.org/srh_home/1996_7/msg00172.html R. R. Karnik, Yuga, Mahāyuga and Kalpa

१क४१. प्राग्गतेः सूर्यमन्दस्य कल्पे सप्ताष्टवह्नयः (३८७)/
१ख४१. कौजस्य वेदखयमा बौधस्याष्टर्तुवह्नयः २०४) //

The computation of the modern value is as follows:
Mean motion of the sun (tropical) 36000.76892 degrees per 100 years
Motion of precession -1.39571 degrees per 100 years
Mean sidereal motion of the sun 35999.37321 degrees per 100 years
Motion of anomaly 35999.04975 degrees per 100 years
Motion of apogee .32346 degrees per 100 years

TRIGONOMETRY

The *Sūrya Siddhānta* contains the roots of modern trigonometry. It uses sine (*jya*), cosine (*kojya* or "perpendicular sine") and inverse sine (*utkram jya*) and continues where the Jaina school left off, and also contains the earliest use of the tangent and secant when discussing the shadow cast by a gnomon in verses 21–22 of Chapter 3:

21. Is the sun's meridian zenith-distance; of that find the base-sine and the perpendicular-sine. If, then, the base-sine and radius be multiplied respectively by the measure of the gnomon in digits,

22. And divided by the perpendicular-sine, the results are the shadow at mid-day…….

$s = \frac{\mathbf{g}\sin\theta}{\cos\theta} = g\tan\theta$

and the hypotenuse of the gnomon at mid-day as
$h = \frac{\mathbf{gr}}{\cos\theta} = gr\sec\theta$

where **g** is the measure of the gnomon is**, r** is the radius of the gnomon, S is the shadow of the gnomon, and **h** is the hypotenuse of the gnomon. We will discuss in detail in Chapter IX the issue of who invented Trigonometry.

CALENDRICAL USES

The Indian solar and lunisolar calendars are widely used, with their local variations, in different parts of India. They are important in predicting the dates for the celebration of various festivals, performance of various rites as well as on all astronomical matters. The modern Indian Solar and lunisolar calendars are based on close approximations to the true times of the Sun's entrance into the various Rāši. Conservative "Panchāngam" (almanac) makers still use the formulae and equations found in the *Sūrya Siddhānta* to compile and compute their Panchānga. The Panchānga is an annual publication published in all regions and languages in India containing all calendrical information on religious, cultural, and astronomical events. It exerts great influence on the religious and social life of the people in India and is found in most Hindu households. In short, the Panchāngam is part of the living tradition, that is unbroken from the Vedic era and the same cannot be said of either Ptolemy or Euclid and the Greek world. Unlike the Ptolemaic tradition which ceased to flourish in the successor Greco Roman world, the Indic tradition has been continuously evolving since the Vedic era.

Quote for the chapter.

Will Durant on the fall of India to the Mughals: "The bitter lesson that may be drawn from this tragedy is that eternal vigilance is the price of civilization. A nation must love peace, but keep its powder dry." Our Oriental Heritage,p.463.

CHAPTER V HISTORICAL PERSPECTIVES PART III KERALA SCHOOL OF ASTRONOMY

THE DEVELOPMENT OF ANALYSIS

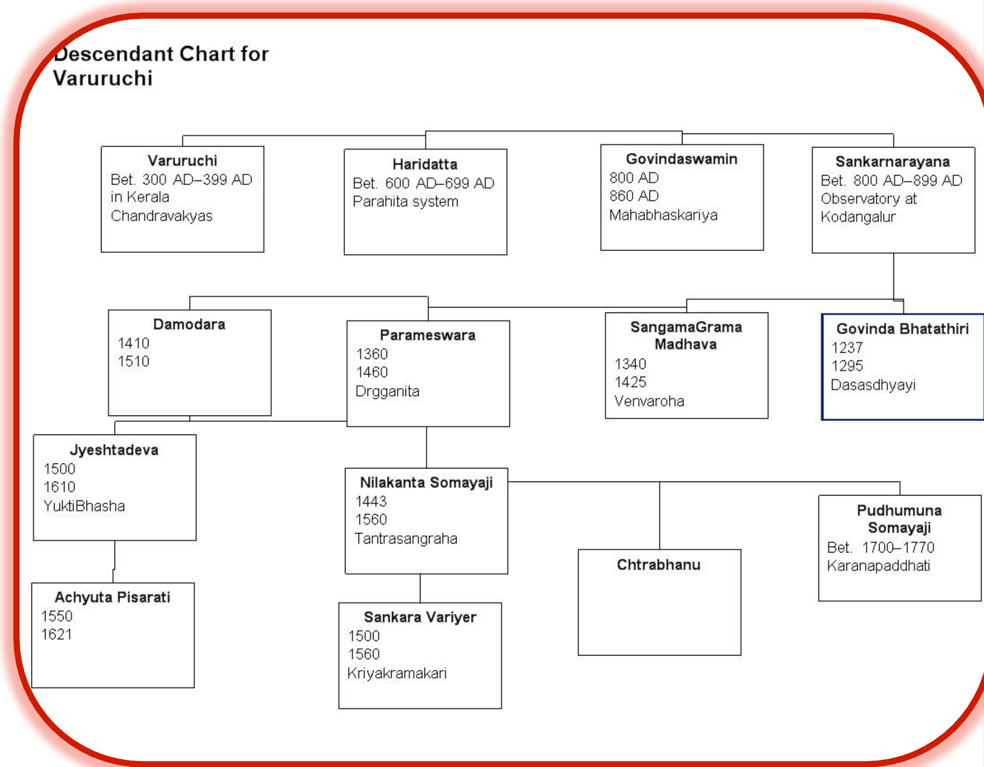
The Kerala School of astronomy and mathematics was a unique development in the history of the computational sciences in India in that it produced an inordinate number of astronomers and mathematicians within a small period of time and within a small geographic area. It was founded by Mādhava of Saṇgamagrāma (c.1340-1425 AD), although its lineage and parampara can be traced back to the beginning of the Common Era, in Malabar, Kerala, South India, which included among its members: The Kerala school is well-known for its pioneering work on mathematical analysis, especially the discovery of infinite series for sine and cosine functions, their pioneering work on the initiation of analysis and the calculus and the development of fast convergent approximations . Their significant contributions in Astronomy, especially in planetary theory, the computation of eclipses and spherical astronomy, are being highlighted only by some recent studies.

In attempting to solve astronomical problems, the Kerala School independently created a number of important mathematics concepts. Their most important results—series expansion for trigonometric functions—were described in Sanskrit verse in a book by Nīlakaṇţa called *Tantrasańgraha*, and again in a commentary on this work, called *Tantrasańgraha-vyakhya*, of unknown authorship. The theorems were stated without proof, but proofs for the series for sine, cosine, and inverse tangent were provided a century later in the work *Yuktibhāṣā* (c. 1500 – c. 1610), written in Malayalam, by Jyeşţhadeva, and also in a commentary on *Tantrasańgraha*.

In Tantrasańgraha, Nīlakaṇţa Somayājī introduced a major revision of the traditional Indian planetary model. He arrived at a unified theory of planetary latitudes and a better formulation of the equation of centre for the interior planets (Mercury and Venus) than was available, either in the earlier Indian works, or in the Islamic or European traditions of Astronomy till the work of Kepler, which was to come more than a hundred years later. Thus the composition of Tantrasańgraha in Nīlakaṇţa was the first savant in the history of astronomy to clearly deduce 1500 CE is indeed a major landmark in the History of Astronomy.

From his computational scheme (and not from any speculative or cosmological argument) that the interior planets go around the Sun and the period of their motion around Sun is also the period of their latitudinal motion. He explains in his Āryabhaţīya bhāṣya that the Earth is not circumscribed by the orbit of the interior planets, Mercury and Venus; and the mean period of motion in longitude of these planets around the Earth is the same as that of the Sun, precisely because they are being carried around the Earth by the Sun.

FIGURE 1 THE GENEALOGICAL TREE OF KERALA ASTRONOMERS. THE GURU SHISHYA (DISCIPLE) GENEALOGICAL TREE {PARAMPARA) OF KERALA ASTRONOMY BEGINS WITH VARARUCHI'S (4TH CENTURY CE) CHANDRAVAKYAS



The diagram gives a pictorial representation of the lineage (teacher-pupil relationships) of the prominent personalities of the Kerala school of astronomy and mathematics. It also shows some of the major figures who flourished in Kerala prior to the emergence of the Kerala school and also some of the individuals of a later period who worked in the traditions of the Kerala school.

In his works, Gola sara and Siddhāntadarpana, Nīlakaņţa describes the geometrical picture of planetary motion that follows from his revised model, where the five planets Mercury, Venus, Mars, Jupiter and Saturn move in eccentric orbits around the mean Sun, which in turn goes around the Earth. Most of the Kerala astronomers who succeeded Nīlakaņţa, such as Jyeşţhadeva, Achyuta Pisārati, Pudhumana Somayājī, etc. seem to have adopted this planetary model.

During 11th-13th March 2000, the Department of Theoretical Physics, University of Madras organized a

Conference, to celebrate the 500th Anniversary of Tantrasańgraha. The Conference was organized in collaboration with the Inter-university Centre of the Indian Institute of Advanced Study, Shimla. The Conference turned out to be an important occasion for highlighting and reviewing the recent work on the achievements in Mathematics and Astronomy of the Kerala School, and the new perspectives in History of Science, which are emerging from these studies.

Even though much of the work of Kerala Astronomers, was Mathematical in nature, they had a significant impact on the manner in which the Panchāngam were calculated and it is to these Kerala Pandits that the Jesuits turned to between 1500 CE and 1560 CE. It is almost a certainty that they were able to translate the contents of Tantrasańgraha (Nilakanta), the Yuktibhāṣā of Jyeșţhadeva, Mādhava's Karana Paddhati among other texts, which would have brought them up to speed on the Indic developments. If the Occidental is so certain that India did not influence Europe in their development of the Calculus, he should have no objection to an investigation into the sources of Euler and the Bernoullis and Pierre Fermat. Both Euler and Bernoulli wrote books on Indian astronomy which are listed in the bibliography. The circumstantial trail is very revealing. Their work, completed two centuries before the invention of calculus in Europe, provided what is now considered the first example of a power series (apart from geometric series). However, it is the contention of the occidental that the Indic did not formulate a systematic theory of differentiation and integration, and that there is no direct evidence of their results being transmitted outside Kerala. We cite the following contemporary individuals, who make such a case, although we feel that the belittling of Indic contributions to the mathematical sciences has been the norm amongst Occidental historians ever since they discovered Sanskrit.

There is considerable opposition in the occident to the notion that the Indian school of Mathematicians, who were by far the largest number of mathematicians in any region till the 18th century (see the listing of Savants in India in the last chapter of the book contains 150 names), when compared to any other country or region in the world and who spanned a continuous period of 3 to 4 millennia, which is also a remarkable attestation of the continuity of the tradition, had also made the beginnings in the field of analysis and Calculus. In fact some Indian Mathematicians go so far as to make a very strong case for "How and why the Calculus was imported to Europe" (see CFM, page 321). In denying such a possibility, the Occidental went out of his way not only to make the opposite case that after the impetus it received from the invasion of the Āryans and the infusion from the Greeks , there was no further progress in India in the exact sciences. They went on to state this proposition and repeat it ad nauseum so vehemently that many Indics today believe that to be the case.

Concomitant with these assumptions there is an unspoken assumption that the tradition is an extinct one and that nobody in India would be able to challenge his presuppositions (Arthāpatti). It is only now 60 years after attaining independence that the realization is dawning on the Indics that the truth is massively otherwise, and that in fact the tradition was alive and well , well into the 18th century and then and only then was it finally extinguished by the colonial overlord. Well, not quite. The tradition is certainly not extinguished, as exemplified by Chandraśekhara Sāmanta of Orissa, who kept the flame alive at the end of the Nineteenth Century. As far as work on series is concerned, we have the 20th century prodigy Srinivasa Ramanujan, the man who loved infinity, and we have Subrahmanyan Chandrasekhar, the astrophysicist whose intellect could penetrate the cosmos and shed light on stars where even light could not escape the force of gravity. While Chandrasekhar could be regarded as a product of the Occidental episteme, the same cannot be said of his uncle Sir C V Raman, who was also a Nobel Laureate in Physics and who received all his education in India. Clearly there is the influence of tradition that is at work here, where most if not all of the practitioners come from a strong traditional background.

We quote below some of the statements about Indic mathematicians and mathematics

Bressoud 2002[146], p. 12) quote: "*There is no evidence that the Indian work on series was known beyond India, or even outside Kerala, until the nineteenth century. Gold and Pingree assert that by the time these series were rediscovered in Europe, they had, for all practical purposes, been lost to India. The expansions of the sine, cosine, and arc tangent had been passed down through several generations of disciples, but they remained sterile observations for which no one could find much use.*" But such an argument, namely that it was lost to India, even if it were true, does not stop them from claiming that the Greeks invented everything. Such a claim is made even though everything was lost in Greece, while they maintain vociferously that it was a continuous tradition and that the Occidental is the true inheritor of the Greek tradition. I also question the statement that the Indian work was not known outside India or even outside Kerala.

Plofker[147], p. 293 Quote: "*It is not unusual to encounter in discussions of Indian mathematics such assertions as that "the concept of differentiation was understood [in India] from the time of Manjula (... in the 10th century)" [Joseph 1991, 300], or that "we may consider Mādhava to have been the founder of mathematical analysis" (Joseph 1991, 293), or that Bhāskara II may claim to be "the precursor of Newton and Leibniz in the discovery of the principle of the differential calculus" (Bag 1979, 294). The points of resemblance, particularly between early European calculus and the Keralese work on power series, have even inspired suggestions of a possible transmission of mathematical ideas from the Malabar coast in or after the 15th century to the Latin scholarly world (e.g., in (Bag 1979, 285)). It should be borne in mind, however, that such an emphasis on the similarity of Sanskrit (or Malayalam) and Latin mathematics risks diminishing our ability fully to see and comprehend the former. To speak of the Indian "discovery of the principle of the differential calculus" somewhat obscures the fact that Indian techniques for expressing changes in the Sine by means of the Cosine or vice versa, as in the examples we have seen, remained within that specific trigonometric context. The differential "principle" was not generalized to arbitrary functions—in fact, the explicit notion of an arbitrary function, not to mention that of its derivative or an algorithm for taking the derivative, is irrelevant here".*

But Plofker's objections to assigning credit to the Indians cannot be taken seriously , since most science is developed by observing specific instances and then in the course of time it is possible to see a pattern which permits the generalization to a broader principle , so when she says that application of a derivative to a trigonometric functions does not make a calculus, she is being disingenuous, because Indic mathematicians were already applying analysis to a large class of functions. It must be conceded that Europe steadily drew ahead after 1700, but the reasons for that have little to do with the work that Indic mathematicians did in the past.

Pingree[148], p. 562 Quote:"*One example I can give you relates to the Indian Mādhava's demonstration, in about 1400 CE, of the infinite power series of trigonometrical functions using geometrical and algebraic arguments. When this was first described in English by Charles Whish, in the 1830s, it was heralded as the Indians' discovery of the calculus. This claim and Mādhava's achievements were ignored by Western historians, presumably at first because they could not admit that an Indian discovered the calculus, but later because no one read anymore the Transactions of the Royal Asiatic Society, in which Whish's article was published. The matter resurfaced in the 1950s, and now we have the Sanskrit texts properly edited,*

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[146] *Bressoud, David. 2002. "Was Calculus Invented in India?" The College Mathematics Journal (Mathematical Association of America). 33(1):2-13.*

[147] Plofker, Kim (2001), "The "Error" in the Indian "Taylor Series Approximation" to the Sine", Historia Mathematica 28 (4): 283-295, see also *http://en.wikipedia.org/wiki/Kerala_school_of_astronomy_and_mathematics*

[148] *Pingree, David (1992), "Hellenophilia versus the History of Science", Isis 83 (4): 554–563, doi:10.1086/356288*

and we understand the clever way that Mādhava derived the series without the calculus; but many historians still find it impossible to conceive of the problem and its solution in terms of anything other than the calculus and proclaim that the calculus is what Mādhava found. In this case the elegance and brilliance of Mādhava's mathematics are being distorted as they are buried under the current mathematical solution to a problem to which he discovered an alternate and powerful solution."

Katz 1995[149], pp. 163-174 Quote:"How close did Islamic and Indian scholars come to inventing the calculus? Islamic scholars nearly developed a general formula for finding integrals of polynomials by CE 1000—and evidently could find such a formula for any polynomial in which they were interested. But, it appears, they were not interested in any polynomial of degree higher than four, at least in any of the material that has come down to us. Indian scholars, on the other hand, were by 1600 able to use ibn al-Haytham's sum formula for arbitrary integral powers in calculating power series for the functions in which they were interested. By the same token, they also knew how to calculate the differentials of these functions. (It is therefore legitimate to conclude) that some of the basic ideas of calculus were known in Egypt and India many centuries before Newton. It does not appear, however, that either Islamic or Indian mathematicians saw the necessity of connecting some of the disparate ideas that we include under the name calculus. They were apparently only interested in specific cases in which these ideas were needed. There is no danger, therefore, that we will have to rewrite the history texts to remove the statement that Newton and Leibniz invented calculus. They were certainly the ones who were able to combine many differing ideas under the two unifying themes of the derivative and the integral, show the connection between them, and turn the calculus into the great problem-solving tool we have today."

We have already quoted Richard Courant (What is Mathematics) in the prologue to this book, where he is less than complimentary on the general tendency of Occidental historians, as is the case with Katz here, when they insist on using the phrase “Newton and Leibniz invented the calculus”. He remarks quite rightly and perceptively in my opinion that the Calculus is a long evolution which Newton and Leibniz did neither terminate nor initiate. What is at stake here is the contribution of the Indics to this long evolution. Here we differ from Katz when he asserts that the Indic contribution played little or no role in the ideas of the Calculus as they floundered around in Europe with only an incomplete understanding of the nature of the limit as the chord metamorphosed to a tangent. On the contrary we wonder why it took 1700 years from the time of Archimedes to evolve to the next step and we find the circumstantial evidence as indicated in table 4 in chapter VIII “Astronomy of the Ancients” to be sufficiently compelling to state that the Indic episteme had a major role in such an evolution. Even more importantly we question the generally negative tone with respect to the Indic contributions while at the same time they continue to study it diligently.

INFINITE SERIES AND CALCULUS

The following is from Wikipedia which in turn relies heavily on the writing of Victor Katz.
“*The Kerala School has made a number of contributions to the fields of infinite series and calculus. These include the following (infinite) geometric series:*

$$\frac{1}{1-x} = 1 + x + x^2 + x^3 \ldots$$

[149] Katz, Victor J. (1995), "*Ideas of Calculus in Islam and India*", Mathematics Magazine (Math). Assoc. Amer.) 68 (3): 163-174*, <http://links.jstor.org/sici?sici=0025-570X%28199506%2968%3A3%3C163%3AIOCIIA%3E2.0.CO%3B2-2>.*

For | x | < 1. This formula, however, was already known in the work of the 10th century Iraqi mathematician Alhazen (the Latinized form of the name Ibn al-Haytham) (965–1039).

The Kerala School made intuitive use of mathematical induction, though the inductive hypothesis was not yet formulated or employed in proofs. They used this to discover a semi-rigorous proof of the result:

$$1^p + 2^p + \ldots + n^p \approx \frac{n^{p+1}}{p+1}$$

For large n. This result was also known to Alhazen.

They applied ideas from (what was to become) differential and integral calculus to obtain (Taylor-Maclaurin) infinite series for sin x, cos x, and arctan x. The Tantrasańgraha-vyakhya gives the series in verse, which when translated to mathematical notation, can be written as:

$$arctan(\frac{y}{x}) = \frac{1}{1}.(\frac{ry}{x}) - \frac{1}{3}.(\frac{ry^3}{x}) + \frac{1}{5}.(\frac{ry^5}{x}) - \ldots,$$ 攊

Where $y/x \leq 1.$

$$r\sin\frac{x}{r} = x - x\cdot\frac{x^2}{(2^2+2)r^2} + x\cdot\frac{x^2}{(2^2+2)r^2}\cdot\frac{x^2}{(4^2+4)r^2} - \cdot$$

$$r - \cos x = r\cdot\frac{x^2}{(2^2-2)r^2} - r\cdot\frac{x^2}{(2^2-2)r^2}\cdot\frac{x^2}{(4^2-4)r^2} + \cdots,$$

Where, for r = 1, the series reduce to the standard power series for these trigonometric functions, for example:

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \cdots$$

(*The Kerala school themselves did not use the "factorial" symbolism.)*

The Kerala School made use of the rectification (computation of length) of the arc of a circle to give a proof of these results. (The later method of Leibniz, using quadrature (i.e. computation of area under the arc of the circle), was not yet developed). They also made use of the series expansion of arctan x to obtain an infinite series expression (later known as Gregory series) for π:

$$\frac{\pi}{4} = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \ldots$$

Their rational approximation of the error for the finite sum of their series is of particular interest. For example, the error, and fi (n + 1), (for n odd, and i = 1, 2, 3) for the series:

$$\frac{\pi}{4} \approx 1 - \frac{1}{3} + \frac{1}{5} - \cdots (-1)^{(n-1)/2}\frac{1}{n} + (-1)^{(n+1)/2} f_i(n+1)$$

Where $f_1(n) = \frac{1}{2n},\ f_2(n) = \frac{n/2}{n^2+1},\ f_3(n) = \frac{(n/2)^2+1}{(n^2+5)n/2}.$

They manipulated the error term to derive a faster converging series for π:

$$\frac{\pi}{4} = \frac{3}{4} + \frac{1}{3^3-3} - \frac{1}{5^3-5} + \frac{1}{7^3-7} - \cdots$$

The ancient Indic gave $\frac{10438}{33215}$ as an approximation for π correct up to 9 decimal places, i.e. 3.141592653*. They made use of an intuitive notion of a limit to compute these results. The Kerala school mathematicians also gave a semi-rigorous method of differentiation of some trigonometric functions, though the notion of a function, or of exponential or logarithmic functions, was not yet formulated."*

The works of the Kerala school were first written up for the Western world by Englishman C. M. Whish in 1835, though there exists some other works, namely **Kala Sankalita** by J. Warren in 1825[150] which briefly mentions the discovery of infinite series by Kerala astronomers. According to Whish, the Kerala mathematicians had "laid the foundation for a complete system of fluxions" and these works abounded "with fluxional forms and series to be found in no work of foreign countries." However, Whish's results were almost completely neglected by his colleagues in Europe, until over a century later, when the discoveries of the Kerala School were investigated again by C. Rajagopal and his associates. Their work includes commentaries on the proofs of the arctan series in Yuktibhāṣā given in two papers, a commentary on the Yuktibhāṣā's proof of the sine and cosine series and two papers that provide the *Sanskrit* verses of the Tantrasańgraha vyakhya for the series for arctan, sin, and cosine (with English translation and commentary).

GEOMETRY, ARITHMETIC, and ALGEBRA

In the fields of geometry, arithmetic, and algebra, the Kerala school discovered a formula for the ecliptic, Lhuilier's formula for the circumradius of a cyclic quadrilateral by Parame ṣvara decimal floating point numbers, the secant method and iterative methods for solution of non-linear equations by Parame ṣvara, and the Newton-Gauss interpolation formula by Govindaswami.

ASTRONOMY

In astronomy, Mādhava discovered a procedure to determine the positions of the Moon every 36 minutes, and methods to estimate the motions of the planets. Late Kerala school astronomers gave a formulation for the equation of the center of the planets, and a heliocentric model of the Solar system.

In 1500, Nīlakaņţa Somayājī (1444–1544) of the Kerala school of astronomy and mathematics, in his *Tantrasańgraha*, revised *Āryabhaţa*'s model for the planets Mercury and Venus. His equation of the centre for these planets remained the most accurate until the time of Johannes Kepler in the 17th century.

Nīlakaņţa Somayājī, in his '*Āryabhaţīya* bhasya', a commentary on *Āryabhaţa*'s '*Āryabhaţīya* ', developed his own computational system for a partially heliocentric planetary model, in which Mercury, Venus, Mars, Jupiter and Saturn orbit the Sun, which in turn orbits the Earth, similar to the Tychonic system later proposed by Tycho Brahe in the late 16th century[151]. Nīlakaņţa's system, however, was mathematically more efficient than the Tychonic system, because it correctly takes into account the equation of the centre and latitudinal motion of Mercury and Venus. Most astronomers of the Kerala School of astronomy and mathematics who followed him accepted his planetary model.

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[150] *Whish, CM, On the Hindu Quadrature of the circle, and the infinite series of the proportion of the circumference to the diameter exhibited in, the four Śāstras, Tantrasańgraha, Yuktibhāşa, Karana Paddhati, and Sadratnamala", Transactions of the Royal Asiatic Society (GB), 3,509-523,1835. However Whish does not seem to have published any further paper on this topic.*

[151] *Tycho Brahe, De Mundi Aetherei Recentioribus Phaenomenis, 1588*

LINGUISTICS
In linguistics, the ayurvedic and poetic traditions of Kerala were founded by this school, and the famous poem, *Narayaneeyam*, was composed by Nārāyaṇa Bhattathiri.

Prominent mathematicians of the Kerala School are listed and their achievements highlighted in the last chapter of this book. While referring to the work of the Kerala mathematicians, both *Arab* and Indian scholars made discoveries before the 17th century that are now considered a part of calculus. However, they were not able to, as *Newton* and *Leibniz* were, to "combine many differing ideas under the two unifying themes of the *derivative* and the *integral*, show the connection between the two, and turn calculus into the great problem-solving tool we have today." The intellectual careers of both Newton and Leibniz are well-documented and there is no indication of their work not being their own; however, it is not known with certainty whether the immediate predecessors of Newton and Leibniz, "including, in particular, Fermat and Roberval, learned of some of the ideas of the Islamic and Indian mathematicians through sources of which we are not now aware."[j] This is an active area of current research, especially in the manuscript collections of *Spain* and *Maghreb*, research that is now being pursued, among other places, at the *Centre national de la recherche scientifique* in *Paris*. … A. K. Bag suggested in 1979 that knowledge of these results might have been transmitted to Europe through the trade route from Kerala by traders and Jesuit missionaries. Kerala was in continuous contact with China and Arabia, and Europe. The suggestion of some communication routes and a chronology by some scholars could make such a transmission a possibility; however, there is no direct evidence by way of relevant manuscripts that such a transmission took place. According to David Bressoud, "there is no evidence that the Indian work of series was known beyond India, or even outside of Kerala, until the nineteenth century."[152]

This statement is not entirely true and in fact it is misleading. We have the avowed statement of the Jesuit Matteo Ricci that he is going to the Malabar coast at the behest of Christopher Clavius (who was in charge of the Vatican effort to make recommendations for what was to become the Gregorian calendar) to collect data as well as learn the technology behind the Indian Jyotish. So we know for a fact that even if their mission to Malabar was a failure it was not for want of trying. This is certainly far more evidence than Pingree ever had when he constantly accused the Indians of plagiarizing from the Greeks, even though there is not a single instance of a Rosetta stone, e.g. the same text in Greek and Sanskrit to identify the mode of transmission. As we have documented in the book the first instance of a Sanskrit translation of a Greek work (through Arabic versions } does not occur till the 18th century l In fact In reality there are far more



[152] *Bressoud, David. 2002. "Was Calculus Invented in India?" The College Mathematics Journal (Mathematical Association of America). 33(1): 2-13.*

texts in India than there ever were in Greece.

But the statement above that research is being done in this area will give them a graceful way out of their dilemma. The mathematicians will probably come out with a statement that will absolve them of all culpability in the matter.

FIGURE 2 ASTROLABE

OTHER ACTIVITY DURING THIS PERIOD

The rest of India was not idle during this period.
Mahendra Sūri pupil of Madana Sūri wrote Yantraraja, a treatise on the Astrolabe in Sanskrit. Probably hailed from Andhra Country. There are a number of Sūris who were astronomers.

Mallikarjuna Sūri:

http://indianmathematicians.blogspot.com/2007/12/mahendra-Sūri.html
Astrolabe [**Universe within one's palm**] is a highly sophisticated astronomical instrument of the pre-modern times. It is a versatile observational and computational instrument. As an observational instrument, it was employed for measuring the altitudes of heavenly bodies and for measuring the heights and distances in land survey. As a computational device, it can simulate the motion of the heavens at any given locality and time. It was also an analog computer for solving numerous problems in spherical trigonometry.

He was a pupil of Madana Sūri. Mahendra Sūri acted as a mediator between the Islamic and Sanskritic tradition of learning.

CHAPTERS OF THE YANTRA RAJA, THE ASTROLABE BY MAHENDRA SURI

The **Yantraraja** or "**the king of astronomical instruments**" is divided into five chapters
Chapter 1: Ganit-ādhyaya provides trigonometrical parameters needed for the construction of astrolabe.
Chapter 2: Yantraghatanādhaya enumerates the different parts of astrolabe.
Chapter 3: Yantraracanādhyaya construction of common northern astrolabe and other variants.
Chapter 4: Yantrasodhanādhyaya the method of verifying whether the astrolabe is properly constructed or not.
Chapter 5: Yantravicaranādhyaya the use of astrolabe as an observational and computational instrument and dwells on the various problems in astronomy and spherical trigonometry that can be solved using astrolabe.

CHAPTER VI
THE INDIAN NATIONAL CALENDAR (INC)

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The **Indian National Calendar** (sometimes called the **Śaka calendar**) is the official civil calendar in use in India. It is used, alongside the Gregorian calendar, by the Gazette of India, news broadcasts by All India Radio, and calendars and communications issued by the Government of India. The INC is basically a Gregorian calendar, with the same structure of leap days as the Gregorian, with elements of the Indian Zodiac grafted in, to indicate where (the name of the Nakṣatra) in the ecliptic the rising of the Sun takes place. It is certainly not a Luni Solar calendar and one cannot tell the phases of the Moon merely by looking at a particular date. So it gives up on the issue of tracking the phases of the moon. It also suffers from falling behind of the dates of the Equinoxes and the solstices, just as the Gregorian calendar does due to the precession of the equinoxes. The calendar is restricted to using the tropical year and the Synodic month. The calendar begins in the Śālivāhana Śaka year of 78 CE and the start of the year takes place at the vernal equinox.

The Planning Committee set up by the Government of India had recommended in 1955 the preparation of an Astronomical Ephemeris and Nautical Almanac for the development of astronomical and astrophysical studies in India. The Calendar Reform Committee formed in 1952 under the Council of Scientific and Industrial Research (CSIR) of the Government of India with the late Prof. M.N. Saha as chairman, recommended the preparation of the Indian Ephemeris and Nautical Almanac incorporating therein, along with the usual astronomical data, the National Calendar of India (the Śaka Calendar) with timings of Tithis (dates), Nakṣatras and yoga calculated with modern astronomical formulae and also with festival dates. It was decided that a special unit attached to a scientific department of the Government of India should do the work. The late Prof. Saha was aware of the works of the late N.C. Lahiri in the field of astronomy and Calendar Reform. In 1952 he called Lahiri to help him in the work of the Calendar Reform Committee as its member-secretary. After completion of the work of the Calendar Committee, Lahiri was entrusted with the work of the Nautical Almanac Unit of the India Meteorological Department as its first officer-in-charge. The unit undertook the preparation of The Indian Ephemeris and Nautical Almanac for 1958 that was the first issue published in March 1957. India is one of the eight countries of the world to prepare and publish such an astronomical ephemeris. The other countries are U.K., U.S.A., Russia, France, Spain, Japan, and China. Apart from Japan and China, India is the only country in Asia to publish an Ephemeris of its own. The neighboring countries depend on this publication for their astronomical data as their requirements are like that of the Indian astronomers and Panchānga-makers.

Tables of Sunrise, Sunset, and Moonrise, Moonset is another publication of the Centre that is in considerable demand by various Government departments, especially the Army, the Air Force and other public concerns and newspapers.

RULES FOR CIVIL USE

Years are counted from the Ṡaka Era; 1 Ṡaka is considered to begin with the vernal equinox of CE 79. The reformed Indian calendar began with Ṡaka Era 1879, Chaitra 1, which corresponds to CE 1957 March 22. Normal years have 365^d; leap years have 366^d. In a leap year, an intercalary day is added to the end of Chaitra. To determine leap years, first add 78 to the Ṡaka year. If this sum is evenly divisible by 4, the year is a leap year, unless the sum is a multiple of 100. In the latter case, the year is not a leap year unless the sum is also a multiple of 400. Table 7a gives the sequence of months and their correlation with the months of the Gregorian calendar.

Can the result of this effort at Calendar reform be termed a lunisolar calendar? As far as the INC (Civil) is concerned, the answer is not really, since the intercalation occurs according to a fixed mathematical formula, rather than any astronomical or Lunar data. The leap years coincide with those of the Gregorian calendar (Calendar Reform Committee, 1957[153]). However, the initial epoch is the Ṡālivāhana Ṡaka Era (SE), a traditional epoch of Indian chronology. Months are named after the traditional Indian months and are offset from the beginning of Gregorian months. The calendar is restricted to using the tropical year. The calendar begins in the Ṡālivāhana Ṡaka year of 78 CE and the start of the year takes place at the vernal equinox.. The date as of May 4, 2009 is Viṡākhā 13, 1931.

In addition to establishing a civil calendar, the Calendar Reform Committee set guidelines for the Rāshtriya Panchānga, which require calculations of the motions of the Sun and Moon and at the instance of the Ministry of Home Affairs the Rāshtriya Panchānga using the Ṡaka era is also being published by this Centre. Tabulations of the religious holidays are prepared by the India Meteorological Department and published annually in *The Indian Astronomical Ephemeris*. Its main objective is to unify the divergent practices existing in different parts of the country and to promote a scientific basis for calendric computations. The first issue for the year 1897 SE (1957-58 CE) was published in June 1957. It is issued in 13 languages, namely English, Hindi, Sanskrit, Urdu, Assamese, Bengali, Oriya, Telugu, Tamil, Malayalam, Kannada, Marathi, and Gujarati. Despite the attempt to establish a unified calendar for all of India, many local variations exist. The Gregorian calendar continues in use for administrative purposes, and holidays are still determined according to regional, religious, and ethnic Traditions. The aim of the reform committee appears to have been a compromise that would retain the simplicity of the solar calendar for civil use, while retaining the luni Solar Panchānga heritage of the Indic civilization for all the other cultural aspects of the society.

HOW MANY ERAS WERE THERE IN ANCIENT INDIA?

ṠAKANRIPA KALA, VIKRAMA SAMVAT, ṠĀLIVĀHANA ṠAKA AND THE SAPTARIṢI TRADITION

There are several eras that are or were in use in India during the last few millennia[154]. Suffice it to say that each of these is used in specific contexts. We will comment only on a few of these. But even amongst this subset there is ambiguity in the nomenclature. The confusion arises because of the use of

[153] *Saha, MN, and NC Lahiri, Report of the Calendar Reform Committee, CSIR, New Delhi, 1992*
[154] *There is an exhaustive listing in Subbarayappa "The tradition of Astronomy in India", page 230.*

the word Ṡaka[155] with more than one meaning. Ṡaka or Samvat means count of years. Ṡāka is used also as a tribal affiliation (the Scythians) or a Dynasty. It is used also with the following names:

> Yudhishtira Ṡaka in 17-12-3139 BCE
> Sudraka Ṡaka in 756
> Sri Harsha Ṡaka in 456 BCE
> Kapilendra Ṡaka in Orissa 1426 CE
> Shivaji Ṡaka in 1673 CE
> The Ṡakanripa Kala is associated with Cyrus of the Persians (Kuru) in 550 BCE (2526 years after Yudhishtira Ṡaka (3076 – 2526) = 550 BCE. This era was used in Kashmir and Punjab etc in the time of Vrddha Garga, in the 6th century BCE, when Northeast Bhārat was briefly under Persian Rule

We are indebted to Arun Upadhyaya for the following clarification

Both the words 'Ṡaka' and 'Samvatsara' indicate count of years, but there is a small technical difference between the two words. The difference will be understood by being cognizant of the social and religious customs and historical changes. Conversely, history can be understood only when the meaning and start of various Ṡaka and Samvatsaras are known. … Ṡaka is considered related to Ṡāka or tribe or the Ṡaka–dvipa (continent) that surrounds or is adjacent to Jambu-dvipa as per Purāṇas. Another misconception is that it was started by Kushana (a branch of the Ṡaka-s) king Kanishka. This assumption has 3 fallacies, (a) As per Rājataraṇgiṇi of Kalhana, three Turkistan chieftains Hushka, Jushka, and Kanishka who ruled from 1294 to 1234 BCE. They were Buddhists, but they had not started any calendar and no calendar is named after them. (b) Ṡalivāhana-Ṡaka started in 78 CE long after period of Kanishka whose period is shifted by 1200 years to make it tally with this era. (c) Ṡalivāhana is not the only Ṡaka- there are Ṡakas in the name of Yudhishtira starting on 17-12-3138 BCE, Ṡudraka in 755 BCE, Shri Harsha Ṡaka in 455 BCE, Kalchuri or Chedi Ṡaka in 248 CE, and various local Ṡakas started by local kings in Nepal (Newar in 889 CE, claimed unification in 1769 CE), Shivaji Ṡaka in 1673 CE, Kapilendra Ṡaka in Orissa 1426 CE etc. None of these kings are Ṡaka.

Even Siddhartha Buddha (1886-1805 BCE as per Purāṇas) is called 'Ṣakyamuni' though he was descendant of Sūryavamshi Ramachandra, not of Ṡaka tribe.

Similarly, only the following years are called 'Samvat'-

1. *Srishti* (creation) *samvat* from which time planetary system of Sun is moving in present manner as per *Sūrya-Siddhānta* (about 1.980 billion years)
2. Parashuram-samvat, called *Kollam* in *Kerala*, starting in 6,177 BC.
3. Kali Samvat starting on 17/18-2-3101 BCE (calendar system without counting 0 AD), Ujjain mid-night.
4. *Vikrama Samvat or Ṡaka* (VṠ) starting in 57 BC is named after *Vikramāditya* of *Paramara-Agni* dynasty of Ujjain, 82 BC to 19 CE. It is surprising that even the astronomers are now using these two words - Ṡaka and *samvatsara*- interchangeably due to ignorance of our *Veda* and *Purāṇas* and depending on deliberately distorted and ignorant European books. *Ṡalivāhana- Ṡaka* is frequently called as '*Ṡaka-samvat*', which has no meaning. It can be Excerpt from either '*Ṡaka*' or '*samvat*', and there are many other Ṡakas, as per examples shown above. I reproduce the excerpt from 'Prof.Narahari Acharts paper presented at Dallas, 2007[156]

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[155] See for instance Kota Venkatachalam 'Indian Eras'

[156] Vepa, Kosla "Astronomical Dating of Events and Select Vignettes from Indian History" Proceedings of seminar held at the Human Empowerment Conference, Dallas, 2007, available at Lulu.com. See chapter 3

"*One of the great blunders of the English historians was to declare that Vikramāditya, the originator of the Vikrama Era never existed and then to identify Chandragupta II of the Gupta dynasty who bore the title of Vikramāditya, as the Vikramāditya and to assign the date of 400 CE for him. Kota Venkatachalam*[157] *has discussed this in great detail. First of all, the Guptas belonged to the 'Sūryavamṣa' and all of them added the title 'āditya' to their names. They ruled Magadha from 328 BCE- 83 BCE with their capital at Pātaliputra. They were contemporaneous with the Greek rulers mentioned earlier. The Greek notices mention Pātaliputra, and not Girivraja or Rājagriha, which was the capital of the Mauryas as has been well known from Buddhist and other records. After Chandragupta II, only four others of the Gupta dynasty ruled for 150 years and finally, the empire was broken up by the Huns. The Gupta inscriptions are available and their own inscriptions mention 'Mālava Gana Ṡaka', who's date begins with 725 BCE. But, the historians have identified it as the Vikrama Ṡaka of 57 BCE and have changed the Gupta Ṡaka from 327 BCE to 320 CE, confusing it with Vallabhi Ṡaka, which started in 319 CE.*

The real Vikramāditya of the Vikrama Ṡaka belongs to the Panwar family and ruled practically the whole of India from Ujjain and originated the Vikrama Ṡaka in 57 BCE. He is the celebrated King whose name is referred to in the work of Kālidāsa. According to the Vaṁṡāvali of Nepal, he conquered Nepal and founded the Vikrama era in 3044 kali or 57 BCE. Veda Vyāsa[54] *quotes the date of the beginning of the Vikrama era as chitra pūrṇima, on February 23, 57 BCE. However, Figure shows the star map for this date and it is not full Moon day. The full Moon occurred on 27th February, but at Hasta. This is in reality an adhika māsa. The chitra pūrṇima occurred on 28th March, 57 BCE. Figure shows the star map for March 14, 57 BCE. It is Ṡukla pratipad, Aṣvini Nakṣatra and would be the beginning for amanta reckoning and February 28, 57 BCE would be the beginning for pūrṇimānta reckoning. The Mālava Gaṇa Ṡaka of Western India tradition would begin on September 21, 57 BCE on Kṛṣṇa Pratipad, Aṡvini Nakṣatra. Professor Sengupta has conclusively established*[158] *that the so called Gupta era (which is identical to the Vallabhi era) cannot be identified with Vikrama Ṡaka, based on the analysis of several 'Gupta Inscriptions'. The former started in 319 CE, where as the starting date for the Vikrama samvat is 57 BCE and has been well chronicled in the dynasty lists from Nepal.*

One hundred and thirty years after Vikramāditya, another Ṡaka was started in 78 CE by Ṡālivāhana, who was really a descendant of Vikramāditya. Here is an account of Ṡālivāhana: "After the death of Vikramāditya, when a century had passed, the tribes of Ṡakas etc. having known about the decline of Dharma in the country, descended with their hordes. Some have come and invaded through the Himalayan passes, others by fording the Sindhu River, still others by sea. They plundered the Āryaland, looted the treasures and captured women…. When things came to this state, was born king Ṡālivāhana. He defeated the Ṡakas; he fixed the boundaries of the Āryaland..." The Ṡālivāhana Ṡaka was started in his honor in 78 CE. He cannot be called a Ṡaka king, so this era has nothing to do with the Ṡaka kāla or Ṡakanṛpati kāla, which refers to the era of the Ṡaka king, Cyrus (Kuru or Kurush) of 550 BCE. Ṡālivāhana Ṡaka has been in use continuously for almost two thousand years and also has nothing to do with King Kanishka, who was a Turuṣka king of Kashmir, and ruled after 150 years after Buddha's Nirvāṇa according to Rājataraṅgiṇi. "

As already noted, according to the Saptariṣi tradition, the seven sages are thought to move through the twenty-seven Nakṣatra-s along the Ecliptic at the rate of one Nakṣatra for 100 years and to complete

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[157] *No history of India would be complete, if it does not include the work of Kota Venkatachalam. This great historian of the modern era remains largely unknown in his own native land despite a record of research and publications that would place him in the category of Will Durant and Arnold Toynbee.*
[158] *Vedavyāsa (1986) p. 238 , Sengupta (1947) p. 248*

one cycle in 2700 years. This forms a convenient cycle for reference and is often chronicled by dropping the century years and giving only the last two digits.

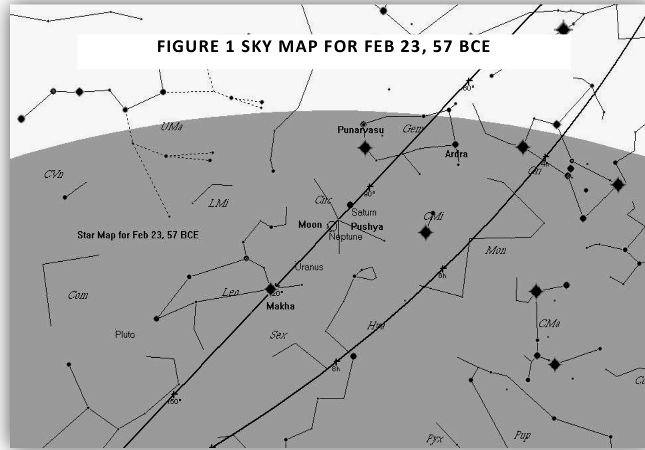


FIGURE 1 SKY MAP FOR FEB 23, 57 BCE

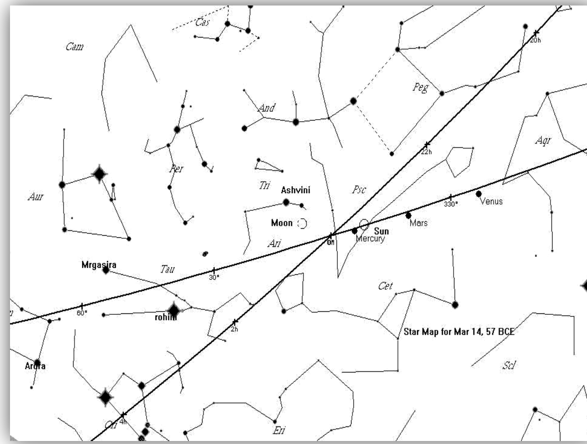


FIGURE 2 SKY MAP FOR MAR 14, 57 BCE

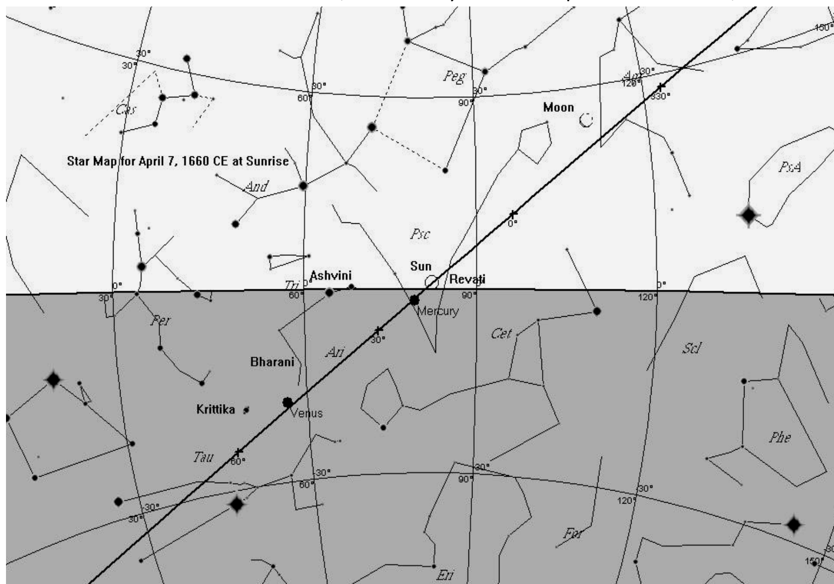
*The **Kaliyuga, Vikrama Śaka, Śālivāhana Śaka** and the **Saptariṣi** traditional reckoning have all been used in a very large number of stone and copper plate inscriptions, manuscript colophons and other*

writings. Kielhorn[159] has listed a large number of those that were available to him in 1891 CE, including 10 dates based on the Saptarṣi tradition, 288 dates based on the Vikrama Śaka, and 370 dates based on the Śālivāhana Śaka. He gives the following rules for conversion: disregarding the hundreds, one must add to the Saptarṣi year of a date 25 to find the corresponding year within one of the centuries of the Kaliyuga, 81 to find the corresponding Vikrama Śaka, and 46 to find the corresponding year in Śālivāhana Śaka.

Of the chronological list of 288 inscriptions and literary works given by Kielhorn[160] using Vikrama Śaka, the earliest is the Bijayagadh stone pillar inscription of Vishnuvardhana of 428 VŚ. and the latest, 1877 VŚ and of the nearly 400 Śālivāhana Śaka dates, the earliest is 169 ŚŚ , a copper plate of the Western Gaṅga king Harivarman, and the latest, 1556 ŚŚ refers to a copper plate of Tirumala Nāyaka of Madurai. Out of the 288 Vikrama listings, ten also quote the corresponding Śālivāhana Śaka year and one quotes Saptarṣi year corresponding to it also. A couple of them include the corresponding Hijira and Vallabhi years.

*Kielhorn also lists five inscriptions, which give dates of solar eclipses and five inscriptions, which give dates of lunar eclipses, all in **Vikrama Śaka.** According to Kielhorn, all the lunar eclipse dates can be verified, but only two of the solar eclipse dates. Our simulations confirm the dates regarding the lunar eclipses. For solar eclipse dates, the simulations confirm the occurrence on four occasions, and the fifth date may in fact be a misreading. Figures show examples of the occurrence of the solar and lunar eclipses respectively. These simulations attest to the veracity of all the three eras **Saptariṣi, Vikrama and Śālivāhana** traditionally used in **Bharata** chronology.*

The names of the 12 months, as also their sequence, are the same in both calendars; however, the New Year is celebrated at separate points during the year and the "year zero" for the two calendars is different. In the Vikrama calendar, the zero years corresponds to 58 BCE, while in the Śalivāhana



[159] *Kielhorn (1969) Kleine Schriften, Franz Steiner Verlag, GmbH, Wiesbaden*
[160] *Kielhorn (1891), "Examination of questions connected with the Vikrama Era", The Indian Antiquary, vol. XX, pp. 124-142.*

calendar, it corresponds to 78 CE. The Vikrama calendar begins with the month of *Baishakh,* Vaiṣākhā (April), or *Kārtika* (October/November) in Gujarat. The Ṡalivāhana calendar begins with the month of *Chaitra* (March) and the Ugadi/Gudi Padwa festivals mark the New Year.

TABLE 1 VIKRAMA AND ṠĀLIVĀHANA CALENDARS (SOLAR MONTHS) THESE MONTHS ARE DERIVED FROM THE CORRESPONDING NAKSHATRA, BUT ARE INTENDEDTO STAY FAITHFUL TO THE SEASONS AND HENCE IT IS TERMED A SOLAR CALENDER

	Month	Length	Start date (Gregorian)
1	Chaitra	30/31	March 22/21
2	Vaiṡākhā	31	April 21
3	Jyeṣṭha	31	May 22
4	Āshādhā	31	June 22
5	Ṡrāvana	31	July 23
6	Bhādrapada	31	August 23
7	Āṡvina	30	September 23
8	Kārtika	30	October 23
9	Agrahāyaṇa Mārgaṡīrṣā	30	November 22
10	Pausha	30	December 22
11	Māgha	30	January 21
12	Phālguna	30	February 20

Another little-known difference between the two calendars exists: while each month in the ṡalivāhana calendar begins with the 'bright half' (Pūrnimanta) and is followed by the 'dark half', the opposite obtains in the *Vikrama* calendar. Thus, each month of the Ṡalivāhana calendar ends with the no-moon (Amāvasya day and the new month begins on the day after that, while the full-moon day brings each month of the *Vikrama* calendar to a close (This is an exception in Gujarati Calendar,, its month (and hence new year) starts on a sunrise of the day after new Moon, and ends on the new Moon, though it follows Vikrama Samvat).

The term may also ambiguously refer to the Hindu calendar, and the Ṡaka era is commonly used by different calendars as well. In leap years, Chaitra has 31^d and starts on March 21 instead. The months in the first half of the year all have 31^d, to take into account the slower movement of the Sun across the ecliptic at this time.

The names of the months are derived from older, Hindu lunisolar calendars, so variations in spelling exist, and there is a possible source of confusion as to what calendar a date belongs to.

Years are counted in the Ṡaka Era, which starts its year 0 in the year 78 of the Common Era. To determine leap years, add 78 to the Ṡaka year - if the result is a leap year in the Gregorian calendar, then the Ṡaka year is a leap year as well.

As already stated the Indian National calendar was introduced by the Calendar Reform Committee in 1957, as part of the Indian Ephemeris and Nautical Almanac, which also contained other astronomical data, as well as timings and formulae for preparing Hindu religious calendars, in an attempt to harmonize this practice. Despite this effort, local variations based on older sources such as the Sūrya Siddhānta may still exist. Usage officially started at Chaitra 1, 1879 Śaka Era, or March 22, 1957. However, government officials seem to largely ignore the New Year's Day of this calendar in favor of the religious calendar. The major problem with the INC Solar Calendar is that it tried to please everybody, but the result was that almost nobody uses it in India today. The reasons for this are not far to seek. The calendar abandoned the Nirayana attribute, preferring instead to go with the Tropical year as in the Gregorian calendar. It tried to maintain an Indian Gloss by naming the months after the Nakṣatra, but it abandoned all pretense of a lunar connection by making it solely a solar calendar. The INC as it stands today must be classed as an Arithmetical Calendar.

PROPOSED STRUCTURE FOR AN ALL INDIA NIRĀYANA SOLAR CALENDAR[161]

- The length of the Sidereal or Nirayana year will be 365.256363^d
- The length of the normal year may well be 365^d,
- The Calendar day will start from midnight IST
- The era for this Calendar will be the Kali era whose epoch is midnight (IST) February 17/18, 3101 BCE or 3102 BC on the Proleptic Julian Calendar or on January 23 on the Proleptic Gregorian calendar (i.e. the Gregorian calendar extended back in time before its promulgation from 1582 October .15).
- The year will start with the month of Vaiŝākhā when the Sun enters the Nirāyana Meṣa rāŝi, which will be April 14, of the Gregorian calendar.
- The first point of Meṣa rāŝi which is the initial point of Nirāyana zodiac is the point in the ecliptic which coincides with the Vernal Equinoctial point of the Verbal Equinox day of 285 CE. This point was then almost opposite the Nakṣatra Chitra (see Figure 3, Solar and Sidereal Zodiac in chapter VII, 173 20 to 186 40.
- The 12 months of the year will have the same names of the 12 Nakṣatras that are currently in use, starting from Vaiŝākhā and ending with Chaitra
- The first 5 months will have 31 days and the last 7 months will have 30 days.

To adjust the uncounted length of .2656363^{d,} there will be a leap year every 4 years, when the length of the year will be 366^d. The Kali year which is divisible by 4 will be deemed as long as a leap year when the month of Phālguna will have 31^{d} .

To adjust the remaining uncounted length of .006363^d of the Nirayana year, there will be additional leap years at cyclical intervals fixed between 150- and 160 years.

RASHTRIYA PANCHĀNGA (THE NATIONAL EPHEMERIS AND ALMANAC)

The Reform Committee also formalized a religious calendar, referred to as the *Rashtriya Panchānga*. This, like many regional calendars, defines a true lunisolar calendar based on the authoritative version of the Sūrya Siddhānta from the 10th century.

[161] *Chatterjee, SK., Indian Calendric System, 2nd edition, Publications division, Ministry of Information and Broadcasting, Government of India,*

The word Panchānga is derived from the Sanskrit *Panchāngam* (*Pancha*, five; *anga*, limb), which refers to the five limbs of the calendar: the Lunar day, the Lunar month, the half-day, the angle of the Sun and Moon , and the solar day.

In the Rashtriya Panchānga, months are determined based on the Sun's position against the fixed stars at sunrise, computed by antipodal observations of the full Moon. This sidereal computation avoids fixed leap year rules, but the number of days in any given month can vary by one or two days. Conversion of dates to the Gregorian calendar, or computing the day of the week, requires one to consult the ephemeris. The lay person therefore relies on the *Panchānga* or Almanacs produced by authoritative astronomical schools.

The Indian Panchanga is truly a technological marvel of high order. It is believed that Śripati solved the problem of simultaneously following the seasons (using a tropical year) and at the same time follow the phases of the moon by naming the days of the month to be congruent with the phases of the moon. But sooner rather than later the piper will have to be paid and an intercalation will have to occur and as far as we know Śripati was the first to come up with the algorithm, and thereby exhibited genius of a high order. It is the only calendar that I know of that uses Astronomical data to self correct itself by refusing to pre-allocate a priori the timing of the intercalary month. Instead it names an Adhika Māsa only when the need arises, e.g. when there is no Rāśi Sankrānti (no ingress into the next Zodiacal sector) in a particular lunar synodic month. As far as I am aware this is unique to the Indic Civilization.

Over time, different authorities producing the Panchānga have varied in their geographical center and other aspects of the computation, resulting in a divergence of a few days in the different regional calendars. Even within the same region, there may be more than one competing authority, occasionally resulting in disagreement on festival dates by as much as a month. The *Rashtriya Panchānga* seeks to resolve such differences.

PRINCIPLES OF THE INDIAN TRADITIONAL CALENDAR OR PANCHĀNGA

Religious holidays are determined by a lunisolar calendar that is based on calculations of the actual positions of the Sun and Moon. Most holidays occur on specified Lunar dates (*Tithis*), as is explained later; a few occur on specified solar dates. The calendrical methods presented here are those recommended by the Calendar Reform Committee (1957). They serve as the basis for the calendar published in *The Indian Astronomical Ephemeris*. However, many local calendar makers continue to use traditional astronomical concepts and formulas, some of which date back 1500 years.
The Calendar Reform Committee attempted to reconcile traditional calendrical practices with modern astronomical concepts. According to their proposals, precession is accounted for and calculations of Solar and Lunar position are based on accurate modern methods. All astronomical calculations are performed with respect to a Central Station at longitude $82^o30'$ East, latitude $23^o11'$ North. For religious purposes Solar days are reckoned from sunrise to sunrise.

A Solar month is defined as the interval required for the Sun's apparent longitude to increase by 30^o, corresponding to the passage (Saṃkrāṇti) of the Sun through a Zodiacal sign (Rāśi). The initial month of the year, Vaiśākhā, begins when the true longitude of the Sun is 23^o 15' (see Table 5.2.1). Because the Earth's orbit is elliptical, the lengths of the months vary from 29.2 to 31.5^d. The short months all occur in the second half of the year around the time of the Earth's perihelion passage.
Lunar months are measured from one New Moon to the next (although some groups reckon from the Full Moon). Each Lunar month is given the name of the Solar month in which the Lunar month begins.

Because most lunations are shorter than a Solar month, there is occasionally a Solar month in which two New Moon s occur. In this case, both Lunar months bear the same name, but the first month is described with the prefix *adhika*, or intercalary. Such a year has thirteen Lunar months. *Adhika* months occur every two or three years following patterns described by the Metonic cycle or more complex Lunar phase cycles.

More rarely, a year will occur in which a short Solar month will pass without having a New Moon. In that case, the name of the Solar month does not occur in the calendar for that year. Such a decayed (*kshaya*) month can occur only in the months near the Earth's perihelion passage. In compensation, a month in the first half of the year will have had two New Moon s, so the year will still have twelve Lunar months. *Kshaya* months are separated by as few as nineteen years and as many as 141 years.

TABLE 2 MAPPING OF SOLAR MONTHS (SAURAMĀSA) OF THE INDIAN RELIGIOUS CALENDAR TO THE LUNAR MONTHS WHICH FOLOW THE NAKṢATRA PARADIGM

Sauramāsa	Rāśior Solar Zodiac		Sun's Longitude deg min	Approx. Duration of month	Rounded	Approx. Greg. Date
1. Vaiśākhā	**वैशाख**	**Meṣa**	23 15	30.9,	31	Apr. 13
2. Jyeṣţha	**ज्यैष्ठ**	**Vṛṣabha**	53 15	31.3	31	May 14
3. Āṣāḍhā	**आशाढ**	**Mithuna**	83 15	31.5	31	June 14
4. Śrāvaṇa	**श्रावण**	**Karka (Greek,Kārkinos)**	113 15	31.4	31	July 16
5. Bhādrapadā	**भाद्रपद**	**Simha**	143 15	31.0	31	Aug. 16
6. Aśvina	**आश्विन**	**Kanya**	173 15	30.5	30	Sept. 16
7. Kārtika	**कार्तिक**	**Tula**	203 15	30.0	30	Oct. 17
8. Mārgaśirṣa	**मार्गशीर्ष अग्रहायण**	**Vṛshchik**	233 15	29.6	30	Nov. 16
9. Pauṣa	**पौष**	**Dhanu**	263 15	29.4	30	Dec. 15
10. Māgha	**माघ**	**Makara**	293 15	29.5	30	Jan. 14
11. Phālguna	**फाल्गुन**	**Kumbha**	323 15	29.9	30	Feb. 12
12. Chaitra	**चैत्र**	Mīna	353 15	30.3	30	Mar. 14

The rationale for this is explained in the section on Mathematics of Intercalation

Lunations are divided into 30 *Tithis*, or Lunar days. Each *Tithi* is defined by the time required for the longitude of the Moon to increase by 12° over the longitude of the Sun. Thus the length of a *Tithi* may vary from about 20 hours to nearly 27 hours. During the waxing phases, *Tithis* are counted from 1 to 15 with the designation *Sukla*. *Tithis* for the waning phases are designated *Kṛṣṇa* and are again counted

from 1 to 15. Each day is assigned the number of the *Tithi* in effect at sunrise. Occasionally a short *Tithi* will begin after sunrise and be completed before the next sunrise. Similarly a long *Tithi* may span two sunrise s. In the former case, a number is omitted from the day count. In the latter, a day number is carried over to a second day.

THE NAMES OF THE MONTHS –SOLAR AND SYNODIC LUNAR

The most common names for the twelve months are shown below. In Vedic times, these were Lunar months, but since the *Sūrya Siddhānta* they are computed on a solar basis. The later months are shorter because on the average, the Sun's motion is more rapid when it is at **perihelion.**

Table 3 which is basically the Indian National Calendar is an agglomeration of disparate entities. The first day and number of days in each month is from the Indian National Calendar which is based on the Vikrama calendar. Note that in leap years (which coincide with the Gregorian), the first month of Chaitra has 31^d instead of 30, and starts on March 21 instead of March 22. The association of seasons or ritus with months is based on religious calendars (including the *Rāshtriya Panchānga*, which has Vaiṡākhā as the first month) - the six *ritus* of two months each constitutes the rituchakra (the cycle of the seasons): Grīshma (summer), Varṣa (rains), Sarat (autumn), Hemanta (late autumn), Sisir (dew, winter), Vasanta (spring). Starting the calendar in Vaiṡākhā avoids the split in the season of Vasanta.

The Nakṣatra-based names of these Synodic Lunar months (e.g. Chaitra, from Chitra), reflect the origin of these names in the Lunar calendar that was used in Vedic times, when an intercalary month (Purushottam) was added as the *adhika māsa* (*extra month*) when the Lunar year went about 30^d behind the Solar calendar. A number of regions still use the purely lunar calendar, but the intercalary month is determined as the month in which the Sun is in the same Rāṡi on two consecutive dark Moons. Thus one may have the two months "Shravana-nija" and "Shravana-adhika" (nija=original, adhika=extra). Lunar months consist of thirty lunar days, or Tithis. A Lunar day is based on the Moon’s position in a Nakṣatra, and the Solar day is measured from sunrise to sunrise. In the Pakṣa system, the lunar days are numbered from the full Moon and the new Moon. A.L. Basham writes in his *The Wonder that was India*: *The vedic calendar had Lunar months split into two Pakṣas of 15 days, with the day (Tithi) being designated by the Moon phase at sunrise (sometimes a Tithi would be skipped if started after sunrise and ended before the next).* The waxing Pakṣa is called Ṡukla Pakṣa, *light half*, and waning Pakṣa the Kṛṣṇa Pakṣa, *dark half*. There are two different systems for making the lunar calendar: **Amanta or mukhya mana system** – a month begins with a new Moon, mostly followed in the southern states, **Pūrnimanta or gauna mana system** – a month begins with a full Moon, followed more in the North.

DIFFERENTIATING LUNAR AND SOLAR MONTHS

How does one identify which of the calendars have Lunar months or Chandramāsa , where the names are based on the Nakṣatra (Sidereal lunar, Luni-solar) and which are solar or Sauramāsa (sidereal solar, tropical solar). There are two criteria that are necessary
If the month names uses Nakṣatra names then they are Lunar or Chandramāsa (sidereal lunar or Luni-solar) in nature. If the names are those of the Rāṣi or the Solar Zodiac then they are definitely Solar months or Suaramāsa and are asynchronous with the phases of the moon. If the month sequence provides a special name for extra month then definitely it is a lunar (sidereal lunar or Luni-solar) month and not a solar month. However in many parts of India they use the Nakṣatra names also for Solar months (Orissa, Bengal, Tripura, Punjab, and Haryana). Hence this criterion is not sufficient to decide on the question.

The Chaitradi (beginning with Chaitra) month names clearly indicate that they are connected to Nakṣatra such as Chaitra, Vaiśākhā, Jyeṣţha etc and so definitely Lunar (sidereal lunar or Luni-solar). The Chaitradi sequence can have an extra month with the name Adhika māsa or Adhi māsa (meaning 'extra month') .Therefore the Chaitrādi sequence is Lunar (sidereal lunar or Luni-solar) in nature.

DIFFERENTIATING SIDEREAL LUNAR AND LUNI-SOLAR MONTHS

How would we identify whether a lunar month is, sidereal lunar or Luni-solar? This can usually be identified based on the definition of the month itself. Further it should be noted that the popular Vedic months are Luni-solar in nature – since they are based on Tithi and Full Moon or New Moon in various Nakṣatras.

Sidereal Lunar Months = 27 Nakṣatra's (27 1/3 solar days)

Sidereal Lunar Year = 324 Nakṣatra days = 27.333 x 12 = 327 solar days

To make such months in tune with the Solar year of 365.2425^d more than one extra month (Adhimāsa) per year would be required in this case; and the extra month should contain 365 – 327 = 38^d.

Synodic Lunar Months = 30 Tithis (29.5 solar days)

Synodic Lunar Year = 29.5 x 12 = 354 solar days

To make such months in tune with the Solar year of 365.2425^d more than *one extra month (*Adhimāsa) per three years would be required in this case; and the extra month should contain (365 – 354 = 11^d per year) x 3 years = 33^d.

This was the system of extra month followed in the Chaitrādi (beginning with Chaitra) sequence.

TABLE 3 MONTHS OF THE INDIAN NATIONAL CALENDAR (SYNODIC LUNAR MONTHS) CHAITRA HAS 31 DAY DURING LEAP YEARS					
	Month Name (Māsa)	Devanagari	Month day 1 (Gregorian)	Number of days	Season Ritu
1	**Chaitra**	चैत्र	**March 22**	30	Vasanta
2	**Vaiṡākhā**	वैशाख	**April 21**	31	Grīshma
3	Jyeșţha	ज्यैष्ठ	**May 22**	31	Grīshma
4	Āṡādhā	आशाढ	**June 22**	31	Varșa
5	Ṡrāvaņa	श्रावण	**July 23**	31	Varșa
6	Bhādrapadā	भाद्रपद	**August 23**	31	Sharat
7	Aṡvina	आश्विन	**September 23**	30	Sharat
8	Kārtika	कार्तिक	**October 23**	30	Hemanta
9	Mārgaṡīrșa (Agrahāyaņa)	मार्गशीर्ष,अग्रहायण	**November 22**	30	Hemanta
10	Paușa	पौष	**December 22**	30	Sisir
11	Māgha	माघ	**January 21**	30	Sisir
12	Phālguni	फाल्गुन	**February 20**	30	Vasanta

The names of the months are based on the longitudinal position of the Moon at mid-month and are the adjectival form of the corresponding Nakșatra (Synodic Lunar Months).

* In a leap year, Chaitra has 31[d] and Chaitra 1 coincides with March 21.

TABLE 4 THE NAMES OF THE SOLAR MONTHS (SAURAMĀSA) ARE AS FOLLOWS:

TABLE 4 THE NAMES OF THE SOLAR MONTHS (Saura Māsa)					
Nr.	Saura Māsa (Rāṡi) (solar months)	**Ritu (season)**	Gregorian months	**Zodiac**	Devanagari
	Meșa	Vasanta (spring)	March/April	**Aries, Ram**	मेष
	Vŗșabha	Vasanta (spring)	April/May	**Taurus, Bull**	व्रषभ
	Mithuna	Grīshma (summer)	May/June	**Gemini, Twins**	मिथुन
	Karka (Greek,Kārkinos)	Grīshma (summer)	June/July	**Cancer, Crab**	कर्क
	Simha	Varșa (monsoon)	July/Aug	**Leo, Lion**	सिंह
	Kanya	Varșa (monsoon)	Aug/Sept	**Virgo, Virgin**	कन्या

Tula	Sharad (autumn)	Sept/Oct	**Libra, Balance**	तुळ
Vṛshchik	Sharad (autumn)	Oct/Nov	**Scorpius, Scorpion**	वृश्चक
Dhanu	Hemant (fall-winter)	Nov/Dec.	**Sagittarius, Archer**	धनु
Makara	Hemant (fall-winter)	Dec/Jan	**Capricornus, Goat horn**	मकर
Kumbha	Shishir(Winter-Spring)	Jan/Feb	**Aquarius, Water pourer**	कुंभ
Mīna	Shishir(Winter-Spring)	Feb/Mar	**Pisces, fish**	मीन

The Solar month is the time spent by the Sun in each Rāśi and it is named after the Rāṡi in which the Sun is found in that month. Hence the names of the months coincide with the names of the Solar Zodiac

SAMVATSARA is a Sanskrit term for "year". In Hindu tradition, there are 60 Samvatsaras, each of which has a name. Once all 60 samvatsaras are over, the cycle starts over again. On occasion, one will be skipped, as the count is based on the Zodiac position of Jupiter, whose period around the sun is slightly less than 12 years (the full cycle of 60 covers five Jovian years).
The value of the Jovian period is 1577917500/ 364224 =4332.272^{d} = 11.86083289^{y}
The sixty Samvatsaras are divided into 3 groups of 20 Samvatsaras each. The first 20 from *Prabhava* to *Vyaya* are attributed to Brahma. The next 20 from *Sarvajit* are attributed to *Prabhava* to Vishnu & the last 20 to Shiva.

THE 60 SAMVATSARAS

TABLE 5 THE SIXTY SAMVATSARAS				
1. Prabhava	2. Vibhava	3. Ṡukla	4. Pramodoota	5. Prajothpatti
6. Āngirasa	7. Shrīmukha	8. Baāva	9. Yuva	10. Dhātru
11. Īshvara	12. Bahudhānya	13. Pramāthi	14. Vikrama	15. Vrusha
16. Chitrabhānu	17. Svabhānu	18. Tārana	19. Pārthiva	20. Vyaya (2006-2007) CE
21. Sarvajith (2007-2008 CE	22. Sarvadhāri	23. Virodhi	24. Vikrutha	25. Khara
26 Nandana	27. Vijaya	28. Jaya	29. Manmatha	30. Durmukhi
31. Hevilambi	32. Vilambi	33. Vikāri	34. Shārvari	35. Plava
36. skipped Shubhakrutha	37. Shobhakrutha	38. Krodhi	39. Vishvāvasu	40. Parābhava
41. Plavanga	42. Kīlaka	43. Saumya	44. Sādhārana	45. Virodhikrutha
46. Paridhāvi	47. Pramādeecha	48. Ānanda	49. Rākshasa	50. Anala
51. Pingala	52. Kālayukthi	53. Siddhārthi	54. Raudra	55. Durmathi
56. Dundubhi	57. Rudhirodgāri	58. Raktākshi	59. Krodhana	60. Akṣaya

REGIONAL VARIANTS

The two calendars most widely used in India today are the Vikrama calendar followed in North India while South Indian states such as Karnataka, Andhra Pradesh and Tamil Nadu follow the Ṡalivāhana calendar. A variant of the Vikrama Calendar was reformed and standardized as the Indian National calendar in 1957 to have constant days in every month (with leap years). Years are counted from 78, year zero of the Ṡaka era. The Bengal Calendar, *Bangabda* (introduced 1584) is widely used in Eastern India. A reformed version of this calendar, with constant days in each month and a leap year system (1966) serves as the national calendar for Bangladesh. Nepal also follows the Vikrama calendar. The same month names and roughly the same periods apply to a number of Buddhist calendars in Sri Lanka, Tibet and other areas.

The traditional Vedic calendar used to start with the month of Agrahāyaṇa (agar = first + Ayana = travel of the Sun, equinox) or Mārgaṡīrṣā. This is the month where the Sun crosses the equator, i.e. the vernal equinox. This month was called Mārgaṡīrṣā after a Nakṣatra around lambda Orionis (see below). Due to the precession of the earth's axis, the vernal equinox is now in Pisces, and corresponds to the month of Chaitra. This shift over the years is what has led to various calendar reforms in different regions to assert different months as the start month for the year. Thus, some calendars (e.g. Vikrama) start with Chaitra, which is the present-day month of the vernal equinox, as the first month. Others may start with Vaiṡākhā (e.g. Bangabda). The shift in the vernal equinox by nearly four months from Agrahāyaṇa to Chaitra in sidereal terms seems to indicate that the original naming conventions may date to the fourth or fifth millennium BC, since the period of **precession** in the earth's axis is about 25,812 years.

TABLE 6 THE 5 ELEMENTS OF THE PANCHĀNGA
Tithi (the day under study)
Vāra (day of the week)
Nakṣatra (the asterism in which the Moon is located)
Yoga (Yoga of the Tithi)
Karana (Karana of the Tithi) –

The Panchāngam, as the name suggests, has 5 distinct pieces of information. To calculate and specify the starting time and ending time of these five quantities is called a Panchāngam. The word calendar is itself of Greek origin. The Indics who devised the calendar faced the same problem that others faced in the ancient world, namely that the periodicities of the Sun and the Moon are not exact integer multiples of one another. So, it is impossible to maintain consistency of seasons and phases of the month concurrently, assuming that the civilization values the information conveyed by both of these sets of data. The resulting calendar while being complex, leaves no room for ambiguity in the interpretation of such a date, and can be maintained accurately with periodic corrections termed Bija.

A lunisolar calendar is always a calendar based on the moon's celestial motion, which in a way keeps itself close to a solar calendar based on the sun's (apparent) celestial motion. That is, the lunisolar calendar's New Year is kept always close (within certain limits) to a solar calendar's New Year. Since the Hindu lunar month names are based on solar transits, and the month of *Chaitra* will, as defined above, always be close to the solar month of *Meṣa*, the Hindu lunisolar calendar will always keep in track with the Hindu solar calendar.

The Hindu solar calendar by contrast starts on April 14–15 each year. This signifies the sun's "entry" into Meṣa Rāṡi and is celebrated as the New Year in Assam, Bengal, Orissa, Manipur, Kerala, Punjab, Tamil Nadu, and Tripura. The first month of the year is called "Chitterai" in Tamil, "Medam" in Malayalam and

Baishakh in Bengali/Punjabi. This solar New Year is celebrated on the same day in Myanmar, Cambodia, Laos, Nepal, and Thailand due to Hindu influence on those countries.

FIGURE 4

MAP OF INDIA SHOWING DIFFERENT CALENDARS IN USE IN DIFFERENT REGIONS



LUNAR MONTH, FORTNIGHTS OR PAKṢA

The Lunar month is divided into two fortnights or Pakṣa, called bright and dark, or, in Indian terms, Śukla or Buddha, and Kṛṣṇa or babul: the bright fortnight, 'The Lunar ' Śukla -Pakṣa, is the period of the waxing Moon , ending at the full-moon; the dark fortnight, Kṛṣṇa-Pakṣa, is the period of the waning Moon , ending at the new Moon . In the amanta or Bulked month, the bright fortnight precedes the dark; in the Pūrnimanta or Kṛṣṇaji month, the dark fortnight comes first; and the result is that, whereas, for instance, the bright fortnight of Chaitra is the same period of time throughout India, the preceding dark fortnight is known in Northern India as the dark fortnight of Chaitra, but in Southern India as the dark fortnight of Phālguna. This, however, does not affect the period covered by the Lunar year; the Chaitradi and Kārttikadi years begin everywhere with the bright fortnight of Chaitra and Varttika respectively; simply, by the amanta system the dark fortnights of Chaitra and Varttika are the second fortnights, and by the Pūrnimanta system they are the last fortnights, of the years. Like the month, the

fortnight begins for religious purposes with its first Lunar day, and for civil purposes with its first civil day.

The Indian Panchāngam is really a cross between an ephemeris and an almanac rather than a calendar. It is really analogous to the concept of a Farmer's almanac that is widely prevalent in the USA, but in addition it contains highly accurate information regarding the Sun, Moon, and the inner planets. The word calendar is itself of Greek/Roman origin. The current calendar "date" based on the Gregorian calendar that we are so familiar with in our daily life is heliocentric and is based on the rotation of the earth around the Sun. It takes the earth approximately 365 ¼ ^{d} to complete its rotation around the Sun. The calendar that most of us use today divides the 365^{d} of earth's period of rotation around the Sun in twelve months. The leap year, which occurs once every four years, accounts for ¼ ^{d} per year. To account for the fact that the tropical year is slightly less than **365.25^{d}**, the reform that the Gregorian calendar made, was to avoid adding a leap day on those centennial years (years divisible by 100) which are not divisible by 400). This makes the effective length of the Gregorian year equal to **365.2425^{d}** and the resulting error accumulates at the rate of **3^{d} in every $10{,}000^{y}$.**
Similar to the solar calendar, the lunar calendar, or more appropriately the Luni-solar calendar is also popular and widely used in the Asian countries such as China, Pacific-rim countries, Middle East countries, and India. The Lunar calendar, which is believed to have originated in India, has been around for a very long time, even long before the solar calendar.

To summarize, the lunar calendar is necessarily Geocentric and is based on the Moon's rotation around the Earth. The Lunar month corresponds to one complete rotation of the Moon around the Earth. Since this period of rotation of Moon around the earth varies, the duration of Lunar month also varies. On average, the Lunar month has about 29 ½ days, the period of the Lunar Synodic orbit. In addition to Moon's rotation around the earth, the Lunar year is based on earth's rotation around the Sun. In general, the Lunar year has twelve Lunar months of approximately 354^{d} (29.5 *12), thus making it shorter by about 11^{d} than the Solar year. However, the Lunar calendar accounts for this difference by adding an extra Lunar month about once every 2 ½ years. The extra Lunar month or intercalary month is commonly known as "*Adhika Māsa*" in India (*Adhika* means extra and the *Māsa* means month). The concept of this extra month is similar to the "Blue Moon" in the West, which occurs almost with the same frequency of 2 ½ years. The Indian Lunar year begins on the new Moon day that occurs near the beginning of the Spring season. The twelve Lunar months are given below.

As mentioned earlier, to account for the difference between the Solar and Lunar year an extra Lunar month occurs about every 2 ½ years as "*Adhika Māsa" or intercalary month* . This is known as Intercalation or embolism. According to the Moslem calendar which is widely followed in Middle East and in other Moslem countries the Lunar year is strictly based on twelve Lunar months of 354^{d} per year. That's why their holy month of *Ramadan* occurs by approximately 11 to 12 days earlier than that in the preceding year.

Thus no calendar can be both (Lunar and Solar). Synchronization can be accomplished with either the Sun or the Moon but not both. Most Lunar calendars attempt to keep the Sun synchronized also, whereas solar calendars pay no attention to the Moon, beyond the division into nominal months.

The Solar day or civil day (commonly referred as the "the date" in western calendar) has a fixed length of 24 hours. The change of date occurs at midnight as per local time or standard time of a given local time zone. Thus, the date changes from midnight to midnight. Similarly the day (as in weekdays) changes from midnight to midnight as per local or standard time for that location. In other words, as per

the western (or English) calendar the length of day and date is exactly 24 hours, and there is a definite correspondence between the date and the corresponding day of the week.
A Lunar day usually begins at sunrise, and the length of Lunar day is determined by the time elapsed between the successive sunrise s. As per the Jewish calendar their lunar day begins at the sunset, and lasts through the next sunset. A Lunar day is essentially the same as a weekday. In India the Lunar day is commonly referred as "*War*" or Vāra. Just as the English calendar has seven days for a week, the Indian calendar has seven *wars* for a week. Thus, the lunar day, however, varies approximately between 22 to 26 hours based on the angular rotation of Moon around the earth in its elliptical orbit. In the Indian calendar, the lunar date is referred as "***Tithi*"**. The basis for the length of a lunar date is geocentric and is defined as the angular distance between the Sun and the Moon as seen from the earth. As the Moon rotates around the earth, the relative angular distance between the Sun and the Moon as seen from the earth increases from 0 degrees to 360 degrees. It takes one Lunar month or about 29 ½ Solar days for the angular distance between the Sun and the Moon to change from 0 to 360 degrees. When the angular distance reaches zero, the next Lunar month begins. Thus, at the new Moon a Lunar month begins, at full Moon, the angular distance between the Sun and the Moon as seen from the earth becomes exactly 180 degrees.

The Lunar cycle begins with new Moon or **Amāvāsyā** and the crescent phase lasts till that phase culminates in the full Moon or **Pūrnima**, typically lasting for about 15 days. Then the Moon enters in the waning phase until it disappears from the sky by lining up with the Sun. The waning phase also lasts for about 15 days. Accordingly in an Indian Lunar month, the crescent lunar phase fortnight is called as "*Shodha or* ***Śukla Pakṣa***" and the waning phase of the Lunar cycle fortnight as "*Kṛṣṇa Pakṣa*". Thus, during *Shodha (or Śukla) Pakṣa* the angular distance between the Moon and the Sun varies from 0 degrees to 180 degrees while that during the *Kṛṣṇa* ***Pakṣa*** from 180 to 0 degrees. If we divide 180 degrees into 15 equal parts, then each part becomes of 12 degrees in length. Thus, this each twelve-degree portion of angular distance between the Moon and the Sun as it appears from the earth is the lunar date or *Tithi*. *Tithis* or Lunar dates in *Shodha (or Śukla) Pakṣa* begin with *Prathama* (first), *Dvitiya* (second), etc. till we reach the *Pūrṇima*, the lunar date for full Moon day. Similarly for the waning fortnight Lunar cycle or *Wada (or Kṛṣṇa) Pakṣa*, *Tithis* begin again with *Prathama* (first), *Dvitiya* (second), etc. till we arrive *Amāvāsyā* or a day before the new Moon. Thus when we refer to *Ramnavami* (the birthday of *Rama*), it's *the Navami* (ninth Lunar day) of *Shudha Pakṣa* of the Lunar month *Chaitra, or Chaitra Shudha Navami*. Similarly, the *Gokulashtmi* (also called *as Janmashtami*, the birthday of ***Kṛṣṇa****)* occurs on *Śrāvaṇa Wadya Ashtami* (eighth Lunar day of *Wadya Pakṣa* of the Lunar month *Śrāvaṇa).*

The angular velocity of the Moon in its elliptical orbit around the earth varies continuously as it is affected (according to Kepler's Law) by the relative distance between the earth and the Moon, and also by the earth's relative distance from the Sun. As a result, the daily angular speed (the speed of the angular change between the Moon and the Sun as seen from the earth) varies somewhere between 10 to 14 degrees per day. Since the length of a *Tithi* corresponds to 12 such degrees, the length of a *Tithi* also varies accordingly. Therefore, a *Tithi* can extend over one day (24 hour period) or it can get shortened if two *Tithis* occur in one 24 hour day.

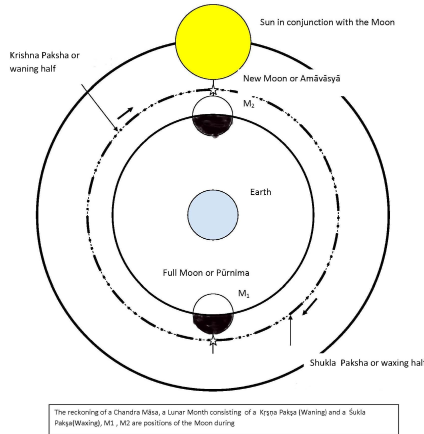
FIGURE 5 KṚṢṆA PAKṢA (WANING HALF) AND ŚHUKLA PAKṢA (WAXING HALF)

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[162] *The words Shukla and Sita mean white or bright in Sanskrit*

Since the angular distance between the Moon and the Sun as referred here is always relative to the entire earth, a lunar day or *Tithi* starts at the same time everywhere in the world but not necessarily on the same day. Thus, when a certain *Tithi* starts at 10:30 PM in India it also begins in New York at the same time, which is 12 PM (EST) on the same day. Since the length of a *Tithi* can vary between 20 to 28 hours, its correspondence to a *War* (a weekday) becomes little confusing.

As per the Indian calendar, the *Tithi* for a given location on the earth depends on the angular distance between the Moon and the Sun relative to the earth at the time of sunrise at that location. Thus, for instance, assume on a November Monday sunrise in New York City occurs at 8:30 AM (EST). Further assume that at 9 AM (EST) on Monday the angular distance between the Sun and Moon is exactly 12 degrees just following the new Moon of the Indian Lunar month *Kartik.* Since the length of a *Tithi* is 12 degrees, the *Tithi, Kartik Shudha Dwitiya* (second day) begins exactly at 9 AM on Monday of that November in New York. However, at the time of sunrise on that Monday the *Tithi Dwitiya* has not begun. Therefore, the *Tithi* for that Monday for city of New York is *Kartik Shudha Prathama* (first day).



The reckoning of a Chandra Māsa, a Lunar Month consisting of a Kŗşņa Pakşa (Waning) and a Śukla Pakşa(Waxing), M1 , M2 are positions of the Moon during

On the same Monday morning the sunrise in Los Angeles occurs well past 9 AM (EST). Since the *Tithi Dwitiya* occurs everywhere in the world at the same instant, therefore, for Los Angeles, the *Tithi* for that Monday would be *Kārtik Shudha Dwitiya.*

For the same Monday at 9 AM (EST), it would be 7:30 PM in Mumbai or New Delhi. Thus, *Tithi* for that Monday for city of New York, Mumbai, and New Delhi is *Kārtik Shudha Prathama* (the first day of Indian Lunar month *Kārtik*) while for most of the regions west of Chicago or St. Louis the *Tithi* for that Monday is *Dwitiya*. In other words, the *Tithi Kārtik Shudha Prathama* for regions west of Chicago or St. Louis should occur on the preceding day, the Sunday.

Kārtik Shudha Prathama (the first day of Indian Lunar month *Kārtik*) also happens to be the first day after *Divali*. Most of the Indians celebrate this as their New Year's Day. Indians living in India, Europe, and eastern part of the United States thus should celebrate their New Year on that Monday while regions west of Chicago should celebrate on the preceding day, the Sunday. (Based on description by Jagdish C. Maheshri) October 12, 2000.

THE MATHEMATICS OF INTERCALATION

One mean Lunar year of twelve lunations measures very nearly **354^{d} 8^{h} 48^{m} 34^{s}**; and one Hindu Solar year measures **365^{d} 6^{h} 12^{m} 30^{s}**. According to *Āryabhaţa*, or slightly more according to the other two authorities. Consequently, the beginning of a Lunar year pure and simple would be always travelling backwards through the Solar year, by about eleven days on each occasion, and would in course of time recede entirely through the Solar year, as it does in the Muslim calendar. The Hindus prevent that in the following manner. The length of the Hindu astronomical Solar month, measured by the Saṃkrāṇtis of the Sun, its successive entrances into the signs of the Zodiac, ranges, in accordance with periodical variations in the speed of the Sun, from about **29^{d} 7^{h} 38^{m}** up to about **31^{d} 15^{h} 28^{m}**. The length of the

amanta or synodic Lunar month ranges, in accordance with periodical variations in the speed of the Moon and the Sun, from about **29^d 19^h 30^m**. Down to about **29^d 7^h 20^m.**

ADHIKAMĀSA & KṢHAYAMĀSA (INTERCALARY & SUPPRESSED MONTHS)

Consequently, it happens from time to time that there are two new-moon conjunctions, so that two lunations begin, in one astronomical Solar month, between two Saṃkrāṇtis of the Sun, while the Sun is in one and the same sign of the Zodiac, and there is no Saṃkrāṇti in the lunation ending with the second new-moon: when this is the case, there are two lunations to which the same name is applicable, and so there is an additional or intercalated month (Adhikamāsa) , in the sense that a name is repeated: thus, when two new-moons occur while the Sun is in Meṣa, the lunation ending with the first of them, during which the Sun has entered Meṣa, is Chaitra; the next lunation, in which there is no Saṃkrāṇti, is Vaiṡākhā, because it begins when the Sun is in Meṣa; and the next lunation after that is again Vaiṡākhā, for the same reason, and also because the Sun enters Vrishabha in the course of it: in these circumstances, the first of the two Vaiṡākhā is called *Adhika Vaiṡākhā*, " the additional or intercalated *Vaiṡākhā*," and the second is called simply Vaiṡākhā, or sometimes Nija-Vaiṡākhā, " the natural *Vaiṡākhā*."

Kathy Deutscher 5/30/2014 1:20 PM
Comment [3]:

On the other hand, it occasionally happens, in an autumn or winter month, that there are two Saṃkrāṇtis of the Sun in one and the same amanta or synodic Lunar month, between two new-moon conjunctions, so that no lunation begins between the two Saṃkrāṇtis: when this is the case, there is one lunation to which two names are applicable, and there is a suppressed month, in the sense that a name is omitted: thus, if the Sun enters both Dhanus and Makara during one synodic lunation, that lunation is Mārgaṡīrṣā, because the Sun was in Vrischika at the first moment of it and enters Dhanus in the course of it; the next lunation is Māgha, because the Sun is in Makara by the time when it begins and will enter Kumbha in the course of it; and the name Pauṣa, between Mārgaṡīrṣā and Magha, is omitted. When a month is thus suppressed, there is always one intercalated month, and sometimes two, in the same Chaitradi Lunar year, so that the Lunar year never contains less than twelve months, and from time to time consists of thirteen months. There are normally seven intercalated months, rising to eight when a month is suppressed, in 19 Solar years, which equal very nearly 235 lunations; and there is never less than one year without an intercalated month between two years with intercalated months, except when there is only one such month in a year in which a month is suppressed; then there is always an intercalated month in the next year also. The suppression of a month takes place at intervals of 19 years and upwards, regarding which no definite statement can conveniently be made here. It may be added that an intercalated Chaitra or Kārtika takes the place of the ordinary month as the first month of the year; an intercalated month is not rejected for that purpose, though it is tabooed from the religious and auspicious points of view.

The manner in which this arrangement of intercalated and suppressed months works out, so as to prevent the beginning of the Chaitradi Lunar year departing far from the beginning of the Meṣa di Solar year, may be illustrated as follows. In 1815 CE the Mesa Saṃkrāṇti occurred on 9 April; and the first civil day of the Chaitradi year was 10 April. In 1816 and 1817 CE the first civil day of the Chaitradi year fell back to 29 March and 18 March. In 1817 CE however, there was an intercalated month, Ṡrāvaṇa; with the result that in 1818 CE the first civil day of the Chaitradi year advanced to 6 April. After various changes of the same kind - including in 1822 CE an intercalation of Aṡvina and a suppression of Pauṣa, followed in 1823 CE, when the first civil day of the Chaitradi year had fallen back to 13 March, by an intercalation of Chaitra itself - in 1834 CE when the Meṣa Saṃkrāṇti occurred again on 11 April, the first civil day of the Chaitradi year was again 10th April.

It might also be called Pauṣa, because the Sun enters Makara in the course of it; and it may be observed that, in accordance with a second rule which formerly existed, it would have been named Pauṣa because it ends while the Sun is in Makara, and the omitted name would have been Mārgasīrṣā. But the more important condition of the present rule, that Pauṣa begins while the Sun is in Dhanus, is not satisfied.

RATIONALE FOR PERIODICITIES OF THE KṢYAMĀSA

We mentioned earlier that a Kṣyamāsa occurs generally once in 141 years, although it may occur less frequently, every 19 years. Bhaskara II mentions in his Siddhānta Śiromaṇi that a Kṣyamāsa may occur in 19,122, 141 years.

Bhaskara estimates there are **1,593,300 INTERCALARY** months in 1 Mahāyuga 4,320,000.

Or dividing both sides by 30 gives the following ratio for $Adhikam\bar{a}sa\ per\ Mah\bar{a}yuga\ =\frac{5311}{14400}$.

Converting the inverse of this (number of years per adhikamāsa) into a continued fraction, we get

$2\ \frac{1}{+1}\ \frac{1}{+2}\frac{1}{+2}\frac{1}{+6}\frac{1}{+1}\frac{1}{+1}\frac{1}{+7}\frac{1}{+8}\frac{1}{+2}.$

The successive convergents of this continued fraction are

2/1, 3/1, 8/3, 19/7, 122/55, 141/62.

The interval between a new moon and a Saṃkrāṇti (the Sun's ingress into a Rāśi) is called a Śuddhi. It expresses the extent to which the Chandramāna gains over the Sauramāna The significance of the convergents is that in 19,122, 141^{Y}, there are respectively 7,55,62 adhikamāsas. Therefore, if there is a Śuddhi of certain duration, the same Suddhi will repeat in durations of 19, 122, and 141 years. This is responsible for the occurrence of a Kṣyamāsa once in 19,122 and 141 years.

Figure Lunar Months in Lunisolar calendar. Note the month is named after the Nakṣatra 180^{o} opposite, when there is a full moon. From http://centralastronomyclass.pbworks.com/ Nayan+Walia+ -+The+Hindu+Lunisolar+Calendar, Nayan Walia - The Hindu Lunisolar Calendar

THE METONIC CYCLE

The well-known Metonic cycle, is attributed to Meton, the Greek Astronomer but the cycle itself is suspected to be of Babylonian origin, and we have been told by some Occidental authors that the cycle was adopted by the Hindus, and elsewhere that the intercalation of a month by them generally takes place in the years 3, 5, 8, II, 24, 16, and 19 of each cycle, differing only in respect of the 24th year, instead of the 13th, from the arrangement which is said to have been fixed by Meton. As regards the first point, however, there is no evidence that a special period of 19 years was ever actually used by the Hindus during the period. (there is speculation that the VJ broaches a 19 year cycle) with which we are dealing, beyond the extent to which it figures as a component of the number of years, 19 X 150 = 2850, forming the lunisolar cycle of an early work entitled Romaka Siddhānta; and, as was recognized by Kalippos not long after the time of Meton himself, the Metonic cycle does not maintain the accuracy has been which sometimes supposed to attach to it, for any extended period; it requires to be readjusted periodically. . It must also be remembered that Yājnavalkya is credited

FIGURE 6 LEGEND FOR FIGURE 7

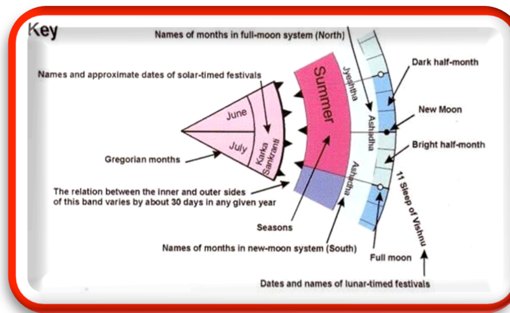


TABLE 8 THE DAYS OF THE INDIAN LUNAR SYNODIC MONTH

TABLE 7 THE METONIC CYCLE
Mean length of the synodic month = 29.5306^d
Mean length of a Lunar year (making up of 12 Lunar months) is $(12 \times 29.5306)^d = 354.3672^d$. In 19 Lunar years with 7 leap months, there are approximately 235 Lunar months or $(19 \times 12 + 7) \times 29.5306^d = 235 * 29.5306 = 6939.6910^d$. --- (A)
For the tropical year, the mean length of the tropical year is 365.2422^d. The Lunar year is short of the tropical year by $(365.2422 - 354.3672)^d = 10.875^d$.
In 19 tropical years, there are $19 \times 365.2422^d = 6939.6018^d$. --- (B)
For the sidereal year, the mean length of the sidereal year is 365.2564^d
The Lunar year is short of the sidereal year by $(365.2564 - 354.3672)^d = 10.8892^d$.
In 19 sidereal years, there are $19 \times 365.2564^d = 6939.8716^d$ --- (C)
The intercalary months are inserted according to a preset mathematical formula and are subject to the same variations in astronomical parameters,

with the 95 year cycle needed for synchronization of the periodicities of the Sun and the Moon. As regards the second point, the precise years of the intercalated months depend upon, and vary with, the year that we may select as the apparent first year of a set of 19 years, and it is not easy to arrange the Hindu years in sets answering to a direct continuation of the Metonic cycle. The *Metonic cycle* is a mathematical rule to determine when a leap month should be added to keep the lunisolar calendar in pace with the tropical or sidereal year. The mathematics behind it is shown below. For the Lunar months, from the above, we see that the lunisolar calendar catches up with 19 sidereal years by adding 7 leap months in every 19 Lunar years interval. This can be seen from values (A), (B), and (C). On average, a leap month is added at a period of 19/7 = 2.7 years. Although the Metonic cycle provides a way of determining occurrence of leap months, not all lunisolar calendars follow this cycle.

Nr.	Kṛṣṇa Pakṣa Waning Moon	Śukla Pakṣa Waxing Moon	Deity and properties
1	Pratipad	Pratipad	The presiding deity of the first Lunar day in Brahma and is good for all types of auspicious and religious ceremonies
2	Dvitiya	Dvitiya	Vidhatr rules this Lunar day and is good for the laying of foundations for buildings and other things of a permanent nature.
3	Trtiya	Trtiya	Visnu is the lord of this day and is good for the cuttings of one's hair and nails and shaving.
4	Chaturthi	Chaturthi	Yama is lord of the 4th Lunar day, good for the destruction of one's enemies, the removal of obstacles, and acts of combat.
5	Panchami	Panchami	The Moon rules this day, which is favorable for administering medicine, the purging of poisons, and surgery.
6	Sasti	Sasti	Karttikeya presides over this day and is favorable for coronations, meeting new friends, festivities, and enjoyment.
7	Saptami	Saptami	The 7th Lunar day is ruled by Indra. One may begin a journey, buy conveyances, and deal with other chores of a movable nature.
8	Astami	Astami	The Vasus rule this day, which is good for taking up arms, building of one's defenses, and fortification.
9	Navami	Navami	The Serpent rules this day, with is suitable for killing enemies, acts of destruction, and violence.
10	Dasami	Dasami	The day is ruled by Dharma and is auspicious for acts of virtue, religious functions, spiritual practices, and pious activities.
11	Ekadasi	Ekadasi	Rudra rules this day; fasting, devotional activities, and remembrance of the Supreme Lord are very favorable.
12	Dvadasi	Dvadasi	The Sun rules this day, auspicious for religious ceremonies the lighting of the sacred fire, and the performance of one's duties.
13	Trayodasi	Trayodasi	The day is ruled by Cupid and is good for forming friendships, sensual pleasures, and festivities.
14	Chaturdasi	Chaturdasi	Kali rules this day suitable for administering poison and calling of elementals and spirits.
15	Amāvāsyā New Moon	Pūrnima Full Moon	The Visve-devas rule the New Moon suitable for the propitiation of the Manes and performance of austerities.

The Indian lunisolar calendars rely on true positions of the Sun and the Moon to determine the occurrence of leap months and the formulas used makes use of astronomical data to determine when a Adhika māsa needs to be added and there is no choice in the matter of using any additional mathematical formulae.

So beyond the use of the concept of an intercalary month there is nothing in common with the 2 approaches. The Indian system is self-correcting and tells us when to intercalate and should be regarded

as an astronomical calendar, whereas the calendar using a Metonic cycle is arithmetical calendar, which is periodically in need of calibration.

AMANTA AND PŪRNIMANTA CALENDAR SYSTEMS

Since either the Amāvāsyā or the Pūrnima , the new Moon or the full Moon, may be taken as the natural end of a Lunar month, there are in use in India 2 systems depending on whether they use the full Moon or the new Moon as the start of the month. If the month ends on Amāvāsyā it is called Amanta, and if it ends on a Pūrnima it is called Pūrnimanta. The remaining 2 items in the Panchanga, the Karana, and the Yoga are not as conceptual and are more derivative in nature.

YOGA

First one computes the angular distance along the ecliptic of each object, taking the ecliptic to start at *Meṣa* or Aries (*Meshādi*, as defined above): this is called the longitude of that object. The longitude of the Sun and the longitude of the Moon are added, and normalized to a value ranging between 0° to 360° (if greater than 360, one subtracts 360.) This sum is divided into 27 parts. Each part will now equal 800' (where ' is the symbol of the arc-minute which means 1/60 of a degree.) These parts are called the *yoga*-s. Legend for Table 9 R = retrograde
Again, minor variations may exist. The *yoga* that is active during sunrise of a day is the *yoga* for the day.

The Planet's orbital period is usually measured with respect to the background stars, on the celestial sphere, and is known as the sidereal period. It can be thought of as the planet's year. The Planets synodic period is the planets orbital period as seen from the earth. This is the time taken by the planet to return to a specific aspect, such as a conjunction or an opposition.

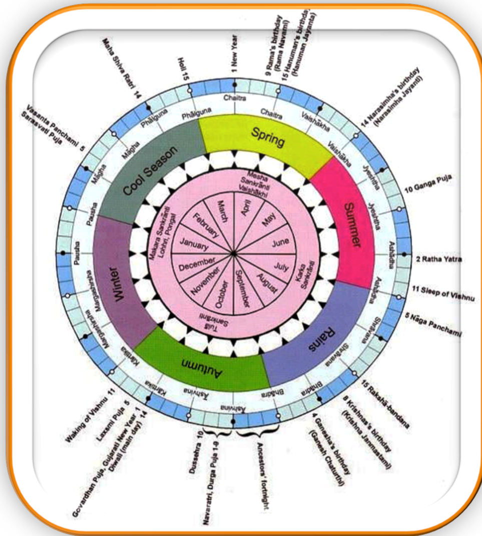
KARANA

A *karana* is half of a Tithi. To be precise, a *karana* is the time required for the angular distance between the Sun and the Moon to increase in steps of 6° starting from 0°. (Compare with the definition of a Tithi above). Since the *Tithi*-s is thirty in number, one would expect there to be sixty *karana*-s. But there are only eleven. There are four "fixed" *karana*-s and seven "repeating" *karana*-s. The "fixed" four *karana*-s are Kimstughna, Shakuni, Chatushpād, and Nāgava. The seven "repeating" *karana*-s is: Bava, Bālava, Kaulava, Taitula, Garajā, Vanijā, Vishti (Bhadrā).
Now the first half of the first *Tithi* (of the bright fortnight) is always *Kimstughna karana*. Hence this *karana* is "fixed". Next, the seven repeating *karana*-s repeat eight times to cover the next 56 half-*Tithi*-s. Thus these are the "repeating" *karana*-s. The three remaining half-*Tithi*-s take the remaining "fixed" *karana*-s in order. Thus these are also "fixed". Thus one gets sixty *karana*-s from eleven. The *karana* active during sunrise of a day is the *karana* for the day.

** Sthira (fixed) karana

TABLE 9 PLANETARY PERIODS AND MOTIONS (SIDEREAL DATA) (NORTONS STAR ATLAS, PAGE 67)

Planet	Mean Sidereal Period	Mean Synodic period(d)	Sidereal Orbital Velocity, Kms^{-1}	Sidereal Mean Daily Motion (Degrees)	Period of Axial rotation	Inclination of Equator to Orbit (Degrees
Mercury Venus Earth	87.96860^{d} 224.7007^{d} 365.2564^{d}	II5.88 583.92 -	47. 87 35.02 29 .79	4.092 1.602 0.986	58.646^{d} 243.019^{d}(R) 23.934^{h}	0.01 177.36 23.44
Mars Jupiter Saturn Uranus Neptune	686.9804^{d} 11.86223^{y} 29.45772^{y} 84.01529^{y} 164.78829^{y} 247.92^{y}	779.9 4 398.88 378.09 369. 66 367.49 366.72	24.13 13.07 9.67 6.84 5.48	0.524 0.083 0.033 0.012 0.006	24.623^{h} 9.842 10.233^{h} 17.240^{h} (R) 16.110^{h}	25.19 3.13 26.73 97.77 28.32



The Sapta Riṣi Kala or Laukika Kala (the epoch of the common man) is in use in Kashmir and in some other parts of India, It is the only mode of reckoning mentioned in the Raja Tārangini. It originates in the supposition that the seven brightest stars in the Ursa Major constellation, move through one Nakṣatra in 100 years (27th part of the ecliptic) and complete one revolution in 2700 years, so that we have one complete era in 2700 years, Kashmiri astronomers make the era begin with Chaitra Śukla 1 of Kali 27 current. Disregarding the hundreds, we must add 47 to the Sapta Riṣi year to find the corresponding Śaka year and 24 – 25 for the corresponding Christian era. The years are Chaitradi.

FIGURE 7 RELATIONSHIP BETWEEN SANKRANTI, RASI, SEASONS AND THE SIDEREAL ZODIAC

TABLE 10 COMPRISON OF SOME ASTRONOMICAL CONSTANTS[163]

Adapted from John Q.bJacobs table in http://www.jqjacobs.net/astro/aryabhata.html

ASTRONOMIC QTY	ĀRYABHAṬA (FROM CLARKE AND KAY)	SŪRYA SIDDHĀNTA	2007 (MODERN)
Years in Cycle ,MY	4,320,000	4,320,000	4,320,000
Rotations, R	1,582,237,500	1,582,237,828	1,582,227,491
Days in a MY, DMY=MY-R	1,577,917,500	1,577,917,828	1,577,907,491
Mean Rotations of earth in SiYr, R/MY=1+DSiYr	366.2586805556	366.2587564815	366.256363639
Lunar Orbits one MY,LO	57,753,336	57,753,336	57,752,984
Days in a Sidereal month, DSiM = 1577917500/57753336 = 27.32166848			
Kaye notes 57,753,339 Lunar orbits rather than 57,753,336 per Clarke.			57,752, 984
Synodic Months MSyn in a MY= LO-MY	53,433,336	53,433,336	53,430,984
Days in a synodic month DSynM= DMY/MSyn = 1,577,917,500/53,433,336=29.53058181 days			29.530588
Mercury orbits in MY= N_{me}	17,937,920	17,937,060	17,937,033.867
Orbital Period of Mercury =R/ N_{me}	88.20631534	88.21054443	87.9686
Venus Orbits in 1 MY=N_v	7,022,388	7,022,376	7,022,260.402
Orbital Period of Venus (days)=R/N_v	225.3133589	225.313744	224.701
Mars Orbits in 1 MY	2,296,824	2,296,832	2,296,876.453
Orbital Period of Mars days ,Years= R/N_{ma}	688.8807449 1.880858089	688.8783455 1.880851538	686.2 1.88
Jupiter Orbits in 1 MY= N_j	364,224	364,220	364,195.066
Orbital Period of Jupiter, Years= R/N_j	11.86083289 years	11.86096315 years	11.86 years
Saturn Orbits in 1 MY= N_s	146,564	146,568	146,568
OrBitLPeriod of Saturn= years – R/N	10795.54 (earth) days =29.47517807 yrs	10795.24745 (earth) day =29.47437367 yrs	10788.8503292 (earth)days=29.4571 yrs

QUOTES ON PEDAGOGY

The second most important job in the world, second only to being a good parent, is being a good teacher." (**S.G. Ellis**)

“You must be the change you wish to see in the world." (Mahatma Gandhi)

"An individual understands a concept, skill, theory, or domain of knowledge to the extent that he or she can apply it appropriately in a new situation." [163] Pedagogy is what our species does best. We are teachers, and we want to teach while sitting around the campfire rather than being continually present during our offspring's trial-and-error experiences."[164]

"In a completely rational society, the best of us would be teachers and the rest of us would have to settle for something less, because passing civilization along from one generation to the next ought to be the highest honor and the highest responsibility anyone could have." (Lee Iacocca, American industrialist; born in 1924)

164 Gardner, Howard The Disciplined Mind: What All Students Should Understand, Simon & Schuster, 1999

165 Gazzaniga, Michael S., Ivry, Richard B. & Mangun, George R. (1998) Cognitive Neuroscience, The Biology of the Mind. New York: W.W. Norton & Company Ltd

CHAPTER VII
ARCHEO-ASTRONOMY AND ASTRO-CHRONOLOGY

THE DATING OF EVENTS BASED ON ARCHAEOLOGICAL MONUMENTS AND ASTRONOMICAL OBSERVATIONS IN ANTIQUITY

Archaeo-astronomy is the dating of events and artifacts based on the astronomical knowledge that is imbedded in the structure or the document. The most famous examples of such structures are obviously the Stonehenge, the pyramids of Egypt, the pyramids of the Maya in Meso America and the Angkor Vat temple in Cambodia. Unfortunately all evidence of such structures in the Indian peninsula have succumbed to the ravages of weather and time and those which were spared such attention by the high humidity environment prevailing in the Indian peninsula were subjected to the butchery, barbarism and destructive bigotry of humankind. Practically the entire population of Indian temples in north India suffered total destruction at the hands of uncivilized bigots who could not stand to see a symbol of a rival faith in their midst. Such savagery continues even today when the statue of the giant Buddha in Bamiyān was systematically destroyed by detonating it with high explosives, all with the tacit approval of the Governments in power in Afghanistan and Pakistan. If the rest of us who consider ourselves civilized, stand by and let these events happen as we did, we will certainly be indicted by the verdict of history as having been deficient in both courage and moral fiber.

While India is deficient in buildings going back to hoary antiquity, when compared to Egypt, it is immensely wealthy beyond any doubt in the quantity and quality of its manuscript wealth. The number that has been identified is over 5 million manuscripts, which is indeed a staggering number by any measure. The real secret to this preservation has been the oral tradition of transmission of information using the highly sophisticated Sūtra technology. Those who destroyed buildings, also destroyed the books in them, but they could not destroy the oral tradition that was still alive. The Mughal Emperor Jahangir was asked why he did not have the Kafirs (infidels) in their midst exterminated, and he is reported to have replied that it could not be done as there were too many.

As we know now, brevity and compression of any text can be accomplished by resorting to encoding. Therein lies the rub. Much of the encoding has been lost and that process is being accelerated as we speak, as the traditional pundits of India, who had the responsibility for keeping alive the flame of knowledge have decided, that the thankless task of interpreting this knowledge is not sufficient recompense for the sacrifices they have to endure in the form of a significantly lower standard of living and the constant ignominy that is heaped upon them by their fellow citizens and a government impervious to those who have little or no political clout. So the knowledge that is contained in these texts will slowly become unintelligible to succeeding generations. Again the fault lies with the Indic himself for electing governments and representatives that have no interest in such a preservation. A small proportion of these texts have survived the onslaught of time, weather, wars, and depredation and these are the ones that are extant today and appear in our bibliography.

The precession of the equinoxes has proved to be very useful for dating certain events in Vedic and Post Vedic times. There are only a few methods, by which we can determine the age of an event in the absence of radiocarbon dating which is not as precise as the astronomical clocks. **Astro-chronology** is the study of Historical events and their chronology, using those historical records which are astronomical in nature. This is not a new development and as we shall see was used by John Playfair,

Hermann Jacobi, Jean Sylvain Bailly, HT Colebrook, and Emmeline Plunket to conclude that in ancient India observational and computational astronomy were both of very ancient vintage.

If we are to use an astronomical observation for chronological purposes, then, four conditions must be satisfied; see for instance the paper by RR Newton[165]

(1) The record of the observation must be basically truthful.

(2) The observation must have the accuracy that we need for the desired chronology. The accuracy of calculation from modern theory is usually not a limiting factor.

(3) The observation must be correctly dated in the ancient calendar.

(4) We must be able to identify the astronomical event uniquely. Identification is usually a problem only with eclipses, although one can imagine circumstances in which it is a problem for other kinds of observation.

For example, we can use the Precession of the Equinoxes (or any of the four cardinal points) to determine the particular Nakṣatra in which one of the cardinal points occurs. If, we recall there are 27 Nakṣatras, it follows that the vernal equinox occurs in a different Nakṣatra (1/27th sector of the ecliptic), approximately once every 956 years (1^{o} every 71.7 years)). But every Yogatārā within a Nakṣatra is not placed equidistantly and care must be exercised in identifying the right Nakṣatra (the one used by the Ancients and its actual RA relative to the mean value (a multiple of 13^{o} 20'). There are occasions when it is clearly stated that the observation is in one of the 4 Padas of the Nakṣatra, in which case the Nakṣatra is merely identified as an ordinal number and not as one of the Yogatārās. One is not restricted to the use of the Precession of the equinoxes and the Solstices for retrodiction of astronomical events. Solar and Lunar eclipses, conjunctions and occultations of other planets, would also qualify as events that can be retrodicted by back calculation capabilities of planetarium software.

We may choose to analyze the statements made in the texts to check for internal consistency. If for example Āryabhaţa uses a place value system, the zero must have been in fairly widespread use by then. If further he uses classical Sanskrit (codified by *Pāṇini* then he must have lived after *Pāṇini.* The use of hermeneutics to analyze and interpret the chronology of various events is another forensic tool.

HERMANN JACOBI (1850-1937) AND BAL GANGADHAR TILAK (JULY 23, 1856, AUGUST 1, 1920)

The subject of Astronomical dating of events was first broached by Jacobi[166] and Tilak[167]. The story of how the work of these 2 came to the attention of Bühler[168] is an interesting tale. It was through Jacobi,

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[165] See endnote in page 310

[166] Jacobi, Hermann. 1909. "On the Antiquity of Vedic Culture." Journal of the Royal Asiatic Society 721-726.

Jacobi, Hermann, 1894, "On the date of the Ṛg. Veda" IA , June 1894, Vol.23, pp.154-159

[167] Tilak - Vedic Chronology and Vedāńga Jyotiṣa (1925) , http://www.scribd.com/doc/26528235/Tilak-Vedic-Chronology-and-Vedāńga-Jyotiṣa-1925;

[168] Professor Johann Georg Bühler (July 19, 1837 – April 8, 1898) was reputedly a scholar of ancient Indian languages and law. Bühler was born to Rev. Johann G. Bühler in Borstel, Hanover, Germany, attended high school in Hanover where he mastered Greek and Latin, then entered university as a student of theology and philosophy at Göttingen, where he studied classical philology, Sanskrit, Zend, Persian, Armenian, and Arabic. In 1858 he received his doctorate in eastern languages and archaeology; his thesis explored the suffix -tês in Greek grammar. That same year he went to Paris to study Sanskrit manuscripts, and in 1859 onwards to London where he remained until October 1862. This time was used mainly for the study of the Vedic manuscripts at the India Office and the Bodleian Library at Oxford University. While in England, Bühler was first a private teacher and later (from May 1861) assistant to the Queen's librarian in Windsor Castle.

In the fall of 1862 Bühler was appointed assistant at the Göttingen library; he moved there in October. While settling in, he received an invitation via Prof. Max Müller to join the Benares Sanskrit College in India. Before this could be settled, he also received (again via Prof. Müller) an offer of Professor of Oriental Languages at the

that Bühler first came to know that there were statements in the RV, calculated to upset the prevailing views on the age of the RV. Whilst Bühler was travelling from Vienna to England in 1892, he stopped at Bonn, to call on Jacobi, his former companion during a tour in the Rajputana desert in the winter of 1873-74. Jacobi assisted Bühler efficiently in the exploration of the Libraries of Jaisalmer and Bikaner. During the talks at Bonn, Jacobi explained his own interpretation of VII 103.9 of the RV, and drew the attention of Bühler to the statements in the Brāhmaṇas regarding the beginning and end of the year as well as regarding the beginning of the 3 seasons of four months each. The indications that the so called Krittika series were not the oldest arrangement of the Nakṣatras known to the Hindus were discussed at length. Bühler congratulated Jacobi for his discoveries.

Six weeks later, the Committee of the Ninth International Oriental conference at London sent Bühler the Manuscript of Orion by Tilak with a request to give his opinion for its being printed in the transactions. He was surprised to find that Tilak's views agreed with those of Jacobi and that Tilak had quoted some of those passages that Jacobi had discussed with him before. Though Bühler differed from Tilak, in some details, he recommended its inclusion in its entirety, containing as it did an important discovery. The transactions, however, when printed included only an abstract of the Orion. The committee pleaded lack of funds to print the entire article. In November of that year, Bühler received from Tilak 2 copies of the abstract at Vienna. One of the copies was sent to Jacobi. Buhler informed him of Tilak's discovery and of the submission of his larger work at the International Oriental conference, London- IA, 1894, p.239.

These works attracted a lot of attention from most of the Indologists in the world at that time and the reaction was uniformly negative especially from those who were influential like Whitney, Thibaut, Biot, Bentley, Winternitz, and Weber. Alas, most of these gentlemen exhibited a Pavlovian reflex, reinforcing our current feeling that the occidental would never countenance, and would in fact fight tooth and nail against a higher antiquity for India. That is precisely what happened. The exception was Bühler who for once broke ranks with his European cohorts and by and large supported the arguments of Tilak and Jacobi. We cite this as an example of the stranglehold that the occident has on Indic history even today. The arguments cited by Whitney and Thibaut are laced with unfavorable generalizations of Indians. Thibaut makes the following remarks about the Hindu astronomer ; "**accuracy of observations, was at no period a strong point of Hindu astronomers … we need only remember that even after the Hindus had reached a comparatively high stage of theoretical astronomical knowledge and probably cultivated systematic observations to some degree, they yet appreciated its importance so imperfectly as to leave no direct record of what they did; astronomers tacitly corrected the astronomical elements they had received from their predecessors, but it did not state what the observations were that appeared to call for these corrections"**. He fails to add that the accuracy of the Indic calculations surpassed that of the Greeks in most instances. India, as we have already noted, has a humid climate, and very little is preserved over long lengths of time and just because we cannot find such records today, we cannot conclude that they never existed.

Elphinstone College, Bombay (now Mumbai). Bühler responded immediately and arrived on February 10, 1863 in Bombay. Noted Sanskrit and legal scholar Kashinath Trimbak Telang was then a student at the college. In the next year Bühler became a Fellow of Bombay University and member of the Bombay Branch of the Royal Asiatic Society. He was to remain in India until 1880. During this time he collected a remarkable number of texts for the Indian government and the libraries of Berlin, Cambridge University, and Oxford University. His contribution to Indology has been vitiated by his insistence that the scripts of India were Semitic in origin. In this he was faithfully following the Hegelian Hypothesis. The episode relating to Vedic chronology is one of the few instances where he took a stand favoring a higher Indic antiquity in part because the evidence was irrefutable.

This was during the time when the Greeks were unable to express a quantity such as the length of the tropical year other than as a rational fraction and they had difficulty determining which of two fractions represented the larger quantity. The Language which Whitney uses is far more condescending and is also laced with innuendo and insult.

FIRST ORDER APPROXIMATION FOR HAND CALCULATIONS

To a first order, the rate of precession is 956^{y} per nakṣatra (13.333^{o}) assuming they are equally spaced on the ecliptic and assuming it is a circular orbit with uniform angular velocity. While calculating the dates the software makes no such assumption and the time between the cardinal points is not assumed to be 6453 years but whatever the program computes, since the angular velocity of the orbiting body (earth) is not necessarily constant. the same holds true for any of the other quantities such as the 25,812 years per revolution of the celestial pole or 71.6 years per degree or 6453 years to precess from equinox to solstice or vice versa.

Currently, the equinoxes and solstices occur in the following Nakṣatra (Table 1). These numbers are more accurate than the first order approximation of assuming the Great cycle of Precession of 25812 Years which is convenient for quick estimates since it is the nearest integer that is commensurate with 27*4 ($1^1 * 2^2 * 3^3$), i.e. is divisible by 27 and 4 but not necessary for the software which uses the latest equation for the rate of precession approved by the IAU. The dates correspond to the day when the Sun is in conjunction with the Nakṣatra. In most cases that we ran the software (Voyager 4.5 Carina software) the difference in the RA of the Nakṣatra and the Sun was less than 2 to 3 seconds of arc length, equivalent to about 12 days, which considering the uncertainties in observation is negligible..

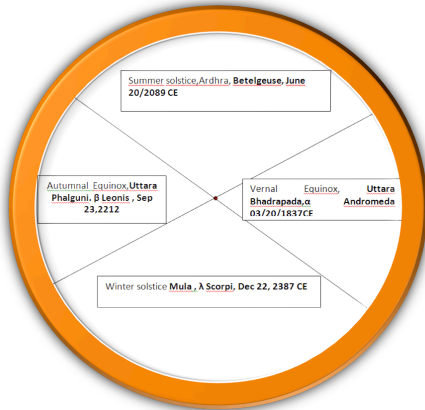


TABLE 1 CURRENT LOCATIONS (2010 OF THE EQUINOXES AND SOLSTICES)

FIGURE 1 NAKSHATRA IN WHICH SOLSTICES AND EQUINOXES OCCUR TODAY

Vernal Equinox - Uttara Bhādrapadā, γ Pegasi Algeneib (March 21, 1743 CE)
Summer Solstice - Ardra or Arudra, α Orionis., Betelgeuse (June 20, 2089 CE
Autumnal Equinox – Uttara Phālguni , β Leonis, (September 23, 2212 CE)
Winter Solstice - Pūrva Āṣāḍhā, (Dec 21,1671 CE) to Mūla, λ Scorpii, (Dec 22, 2387CE),

TABLE 2 THE CURRENT SEQUENCE OF NAKṢATRAS BEGINS WITH UTTARA BHĀDRAPADĀ
Read sequentially left to right

1. Uttara Bhādrapadā γ Pegasi, Algeneib	**2. Revati, Eta Piscium**
3. Aṣvini, α Arietis	**4. ApaBharani, Musca, 41 Arietis**
5. Krittika, Alcyone	**6. Rohiṇi, Aldebaran**
7. MrigaŚīrṣā, β Tauri, ElNath	**8. Ardra, Betelgeuse**

9. Punarvasu, β Geminorium, Pollux	**10. Pusya, δ Cancri, Assellus Australis**
11. Āśleṣā, alpha Cancri, Acubens	**12. Magha, α Leonis, Regulus**
13. Pūrva-Phālguni, delta Leonis, Zosma	**14. Uttara-Phālguni, β Leonis, Denebola**
15. Hasta, γ Virginis, Porrima	**16. Chitra, alpha Spica**
17. Swāti, PI Hydrae, 49, Hydrae	**18. Viśākhā, β Librae, Zubeneschamali**
19. Anurādha, δ Scorpii,	**20. Jyeṣţha, alpha Scorpii, Antares**
21. Mūla, Lambda Scorpii, Shaula	**22. Pūrva Āṣāḍhā, δ Sagittarii, Kaus Meridionalis**
23. Uttara Āṣāḍhā, τ Sagittarii	**24. Srāvana, β Capricornus**
25. Dhanishta, Sravishta, delta Capricornus, Deneb- algeidi	**26. Satabhisaj, Lambda Aquarii,**
27. Pūrva Bhādrapadā, Markab, α Pegasi.	

TABLE 3 ASTRONOMICAL OBSERVATIONS RETRODICTED BY PLANETARIUM SOFTWARE AT THE 4 CARDINAL POINTS RETRODICTED NAKṢATRA EVENT TABLE (RNET)

NR	NAKṢATRA	WESTERN ZODIAC & OTHER NAMES	WINTER SOLSTICE	VERNAL EQUINOX	SUMMER SOLSTICE	AUTUMNAL EQUINOX
1	Aśvini, Mean N_{yp} = 25,785	α ,β Arietis	Feb 11, 7313 BCE, Dec 3, 18310 CE(25,623)	Mar 25, 401 BCE, Feb 19, 25098 CE (25499)	Nov 5, 20362 BCE Jun 17, 5721 CE (26,083)	Sep 9, 11693CE Dec 26, 14244 BCE (25937)
2	Apabharani	41 Arietis, Musca	Feb 17, 8272 BCE	Apr 4, 1623 BCE	Jun 19, 4786 CE	Dec 31, 14898 BCE
3	Krittika	η,π,Tauri, Pléiades, *Alcyone 27* or 28 Tauri	Feb. 22, 8947 BCE Dec 5, 16738 CE, (25686)	Apr 8, 2220 BCE, Feb 22, 23291 CE(25511)	Nov 2, 21891 BCE, Jun 19, 4139 CE (26030)	Dec 31, 15622 BCE Sep 13, 10308 CE, (25928)
4	Rohiṇi	α Tauri, Aldebaran	Feb 28, 9654 BCE	Apr 16, 3247 BCE	Jun 20, 3442 CE	Sep 13, 9904 CE
5	Mrigaśīrṣā, (Jacobi)	112 β Taurii, El Nath	Dec 7, 15150 CE Mar 6, 10608 BCE	Apr 21, 3835 BCE	June 21, 2531 CE	Sep 14, 8696 CE
6	Ardrã	α Orionis Betelgeuse	March 9, 11038 BCE Dec 8,14739 CE	Apr 30,5011 BCE	Jun 20, 2089 CE	Sep 15, 8911 CE
7	Punarvasu	β Geminorium, Pollux	Dec 10, 13008 CE	May 7, 6048 BCE	Jun 21, 332 CE	Sep 18, 6517 CE
8	Tisya or Pusya (Pargiter, Siddharth)	δ Cancri	Dec 11, 11936 CE	May 17, 7414 BCE(Siddharth p.73)	Jun 30, 790 BCE	Sep 19, 5631 CE
9	Āśleṣā	α Cancri 1,2	Dec 13, 11543 CE	May 20, 7953 BCE	Jul 3, 1149 BCE	Sep 20, 5443 CE
10	Magha	α Leonis, Regulus	Dec 13,10465 CE	May 27, 8953 BCE	July 13, 2324 BCE	September 21,4132 CE

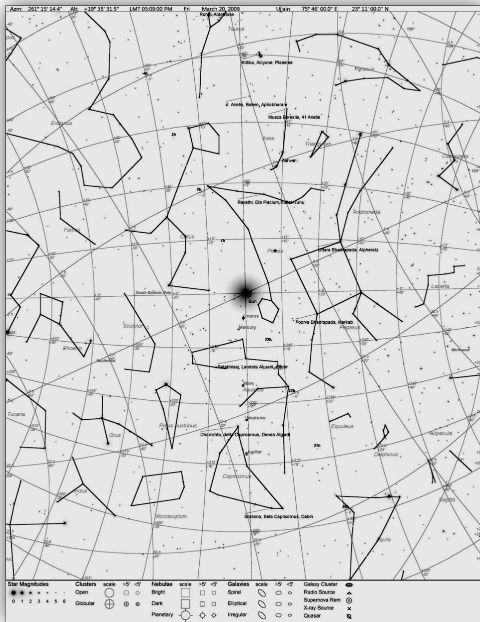
1)	Indian name	Western Zodiac name	WS	VE	SS	AE
11	Pūrva Phālguni	δ Leonis	Dec 15,9648 CE	May 30, 9306 BCE	July 19, 3151 BCE	Sep 21, 2880 CE
12	Uttara Phālguni, Jacobi	β Leonis	Dec 16, 8933 CE	June 4, 10131 BCE	July 24, 3903 BCE (Jacobi)Tilak	Sep 23, 2212 CE
13	Hasta	Γ Virginis. Porrima	Dec 18, 7647 CE	June 15, 11814 BCE	Aug 2, 5271 BCE	Sep 16, 1185 CE
14	Chiträ	α Virginis, Spica	Dec 20,6690 CE	Jun 21,12973 BCE	Aug 8, 6284 BCE	Sep 22, 349 CE
15	Swāti	Pi Hydrae	Dec 20 , 5654 CE	Mar 15, 11534 CE	Jun 6, 18243 CE Jun 1, 7389 BCE (25632)	Sep 28, 370 BCE
16	Viŝākhā	β Librae.	Dec 20,4888 CE	Mar 15,11409 CE	Aug 20, 8147 BCE	Oct 8, 1847 BCE
17	Anurādhā	δ Scorpii , Jacobi	Dec 22, 3955 CE	Mar 16,10190 CE	Aug 26, 9135 BCE	Oct 12, 2476 BCE
18	Jyeşţha	α Scorpii, Antares	Dec 22, 3443 CE	Mar 17, 9153 CE	Aug 29, 9667 BCE	Oct 14, 2921 BCE
19	Mūla	λ Scorpii	Dec 22, 2387CE	Mar 18, 8299 CE	Sep 5, 10766 BCE	Oct 20, 3702 BCE (Jacobi)
20	Pūrva Asādhā	δ Sagittarii	Dec 21, 1671 CE	18, 7828 CE	Sep 9, 11489 BCE	Oct 27, 4682 BCE
21	Uttara Asādhā	τ Sagittarii	Dec 16, 935 CE	Mar 19, 7194 CE	Sep 13, 12236 BCE	Oct 31, 5484 BCE
22	Śrāvaņa	β Capricornus ,Dabih	Dec 25, 453 BCE	Mar 19, 6111 CE	Jun 11, 12268 CE	Nov 10, 7228 BCE
23	Dhanistā (Sravishta)(1)	δ Capricornus Deneb al Geidi	Jan 5 , 1861 BCE Vedāṅga Jyotişa	Mar 19, 4512 CE	Jun 24, 10903 CE	Nov 18, 8419 BCE
24	Satabhisaj	λ Aquarii	Jan 14, 3181 BCE	Mar 21, 3303 CE	Jun 28, 10234 CE	Nov 26, 9604 BCE
25	Pūrva Bhādrapadā(Jacobi) BG Siddharth	α Pegasi (Markab)	Jan 19, 4072 BCE (Jacobi)	Mar 20, 3092 CE	Jun 16, 8836 CE	Dec 7, 11413 BCE
26	Uttara Bhādrapada	γ Pegasi Algeneib	Jan 28, 5217 BCE	Mar 21, 1743 CE	Jun 16, 7729 CE	Dec 14, 12290 BCE
27	Revati	η Piscium	Dec 1, 19075 CE, Feb 5, 6507 BCE	Mar 21, 238 CE	Jun 16, 6483 CE	Dec 9, 12585 CE Dec 19, 13304 BCE

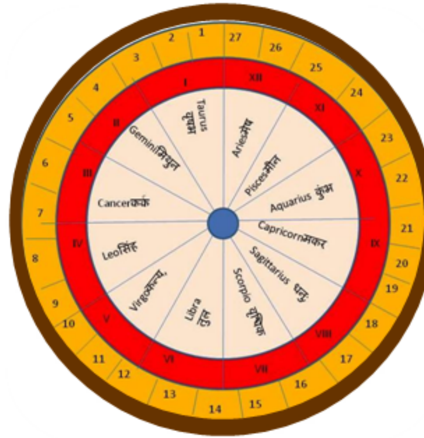
TABLE 4 CARDINAL POINTS OBSERVED DURING THE AṢVINI ERA
Vernal Equinox at Aśvinī 401 BCE
The winter solstice occurred in Śrāvaņa 453 BCE
The summer solstice in Pusya, 790 BCE
The autumnal equinox in Swati , 370 BCE

FIGURE 2 THE SKY MAP FOR VE IN UTTARA BHĀDRAPADĀ,

FIGURE 3 THE SEQUENCE OF STARS BEGINNING WITH ASVINI, 400 BCE

TABLE 4B CARDINAL POINTS OBSERVED DURING THE MRIGAŚĪRṢĀ ERA
VE IN MRIGAŚĪRṢĀ 3835 BCE





The winter solstice occurred at 3^{o} 20’ of the divisional Uttara Bhādrapadā – indicates a date of 4570 BCE (not the Yogatārā or Junction Star)
The summer solstice in 10^{o} of Uttara Phālguni 3830 BCE
The autumnal equinox in the middle of Mūla 3750 BCE

Aṣvini, α Arietis
ApaBharani, Musca, 41 Arietis
Krittika, Alcyone
Rohiṇi, Aldebaran
Mrigaśīrṣā, β Tauri, ElNath
Ardra, Betelgeuse
Punarvasu, β Geminorium, Pollux

Pusya, δ Cancri, Assellus Australis, Āśleṣā, alpha Cancri, Acubens, Magha δ, α Leonis, Regulus, Pūrva-Phālguni, delta Leonis, Zosma, Uttara-Phālguni, β Leonis, Denebola, Hasta, γ Virginis, Porrima, Chitra, α Spica,
Swāti, PI Hydrae, 49, Hydrae,
Viśākhā, β Librae, Zubeneschamali, Anurādha, δ Scorpii, Jyeşţa, alpha Scorpii, Antares,
Mūla, Lambda Scorpii, Shaula,
Pūrva Āṣāḍhā, δ Sagittarii, Kaus Meridionalis,
Uttara Āṣāḍhā Scorpii, Shaula,
Srāvaṇa, β Capricornus
Dhanishta, Sravishta, delta Capricornus, Deneb- algeidi
Satabhisaj, Lambda Aquarii,Pūrva Bhādrapadā, Markab, alpha Pegasi, Uttara Bhādrapadā, γ Pegasi, Algeneib
Revati, Eta Piscium

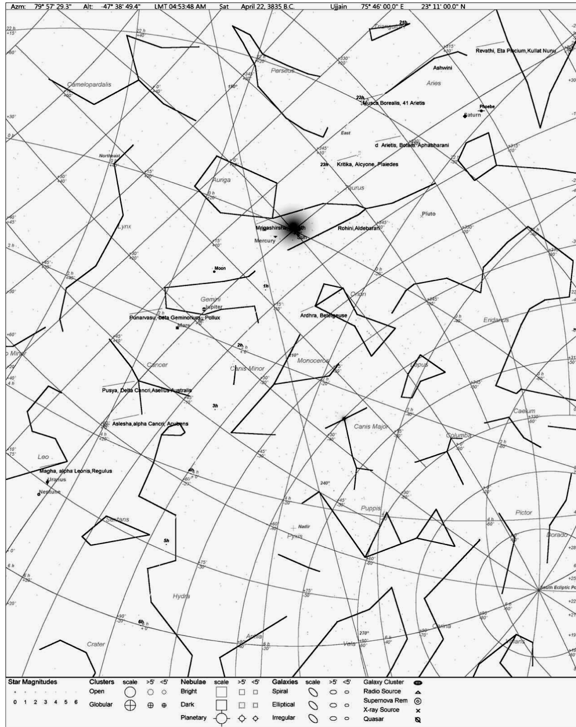


FIGURE 4 THE SKY MAP FOR VE IN MRIGAŚĪRṢĀ APR 21, 3835

THE FOLLOWING PARAGRAPHS (ITALICIZED) ARE EXCERPTED FROM THE PAPER BY PROFESSOR NARAHARI ACHAR (2009)

THE LEGEND OF YAMA AND HIS TWO DOGS

This legend occurs in RV X.14, in the following two verses: "pass by a secure path beyond the two spotted four-eyed dogs, the progeny of sarama and join the wise pitrus who rejoice fully with Yama. Entrust him, o king, to thy two dogs which are thy protectors, Yama, the four-eyed guardians of the road, renowned by man, and grant him prosperity and health"[169]. The astronomical interpretation according to Sengupta is that the two stars, α-Minoris and α-Canis Major are pointed to the south celestial pole. In other words, this referred to a time when the two stars crossed the meridian at the same time or, the two had the same right ascension.

THE LEGEND OF MUNDAKAS

The so called 'Frog Song', is the famous Suktam in RV, VII.103. Jacobi finds in this Sukta a reference to the beginning of the year in the rainy season, which occurs after the summer solstice. According to

[169] *Wilson's translation*

Jacobi, the first rainy month was Bhādrapadā, the full Moon near the Nakṣatra Prosthapada with the summer solstice occurring in the Uttara Phālguni Nakṣatra. Jacobi finds support for his argument from the ritual of upākana mentioned in the dharma and Gṛhya Sūtras. As Law has pointed out, this hymn VII.103 should not be considered in isolation, but along with two previous hymns, VII.101 and 102. These three are prayers addressed to Pārjanya for rain. Nirukta also indicates that this hymn is an invocation by Vaśiṣţa to Pārjanya for rainfall. Law indicates that summer solstice in Uttara Phālguni (3903 BCE) also corresponds to vernal equinox in Mrigaśīrṣa (3835 BCE).

DATA IN THE PURĀṆAS, ITIHĀSA, AND IN THE SIDDHĀNTAS

*Sūrya Siddhānta states that Sun was 54 degrees away from vernal equinox when Kaliyuga started on a new Moon day, corresponding to February 17/18, 3101 BCE, at Ujjain (75d47m 23o 15' N).. This is borne out by Voyager software which gives R.A of 20h 28' 41.5". That gives an angular distance of (24 - 20.47)*15 = 53 degrees.*

VARĀHAMIHĪRA AND THE IDENTIFICATION OF SAKANRIPATIKALA

Varāhamihīra stated that, 2526 years before the start of the Śaka era[170] *as per text below: When Saptariṣi (Ursa Major) was near Magha Yudhistira was king 2526 years before Śaka time. Historians have assumed that the Śakakala or Śakanripatikala refers to the Śālivāhana Śaka of 78 CE. Thus arriving at the date -2448 (= 78-2526) or 2449 BCE for the Yudhishtira Era, the scholars declare that Varāhamihīra gives this as the date of the MBH war. Presently, traditional Sanatana Dharma followers consider that Kaliyuga started at 3101 BCE, when Sri Kṛṣṇa passed away, and that MBH war occurred in 3137 BCE. Millennium year 2000 CE is Kali 5102. Varāhamihīra simply quotes Vriddha Garga's opinion regarding when Yudhishṭhira lived and how to get that period from Śakakala and this is not Varāhamihīra's opinion. Garga by all accounts lived before CE and the word Śakakala of Garga cannot refer to Śalivāhana Śaka of 78 CE. The Śakakala or Śakanripatikala in Garga's words refers to the era of the Śaka king, Kurush or Cyrus (Persia), beginning with 550 BCE. All this has been noted by many scholars, and discussed in great detail by Kota Venkatachalam, whose work may be consulted for further details. With the correct identification of Śakakala, the date given by Varāhamihīra is also consistent with the date of the war given here. It may be noted in passing that it was based on the wrong identification of Śakakala that Professor Sengupta felt justified in his date of 2449 BCE for the war. Thus the so called Varāhamihīra tradition and the Rājataraṅgiṇi tradition of assigning a date of 2449 BCE to the war is based on a mistaken identity for the Śakakala compounded by the mistake in assuming that a mere quotation of Vriddha Garga by Varāhamihīra reflects the latter's own opinion. The date derived here is consistent with Āryabhaṭa tradition and the correct Śakakala beginning in 550 BCE.*

Kālhāṇa also assumes that the position of Saptariṣis has been given by Varāhamihīra and makes the same mistake regarding the Śakakala in his Rājataraṅgiṇi. However, he assumes that Kaliyuga began in 3101 BCE, hence declares that Pandavas lived 3101-2449= 652 years after the start of the Kaliyuga. This has only contributed to the confusion and some Indologists actually declare Kaliyuga as a figment of imagination. The Bhishma Parva and Udyoga Parva (specific chapters of MBH) provide considerable astronomical/astrological descriptions and omens as the MBH war was approaching. It describes a period of draught, with many planetary positions. Then there is this clear reference to pair of eclipses occurring on 13th day, Fourteenth day, Fifteenth day and in past Sixteenth day but we have never known the Amāvāsyā (New Moon day) to occur on the thirteenth day. Lunar eclipse followed by solar eclipse on thirteenth day is in single Lunar month etc…

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[170] *Brihat Saṃhita, Chapter 13, sloka 3*

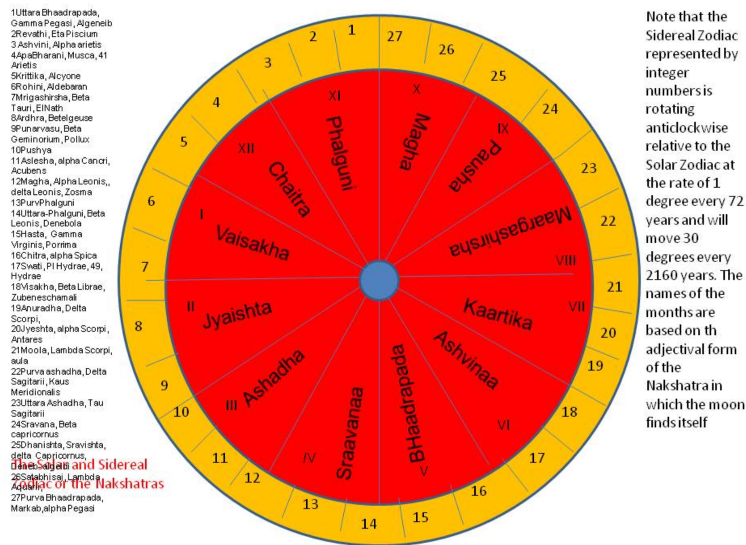
Varāhamihīra stated that 2526 before the start of Ṡaka, Yudhishtira was the ruling king. If the Ṡaka era was Vikrama Ṡaka it would make Yudhisthira as king in 2583 BCE, which is before MBH War.

However if the Ṡaka era was Ṡakanripakala, of the Persian Monarch Kuru (Greek corruption Cyrus) of the Haxamanish Dynasty, then such an era commenced on 550 BCE. If that was the case then 2526 + 550 = 3076 BCE, coincides with, Yudhisthira's death 25 years after the beginning of Kaliyuga. Kuru had control for a brief period of the northwest comprising of present day Afghanistan and present day Pakistan west of the Indus and its tributaries. Hence the use of the Ṡakanripakala era in India for a brief period thereafter.

FIGURE 5 THE ORDER OF THE STARS BEGINNING WITH UTTARA BHĀDRAPADĀ CIRCA 2000 CE, INCLUDING THE CORRESPONDING SOLAR MONTHS.

IN RV 10.64.8 Tishya (δ Cancri) is invoked. The VE occurs in Tishya in 7414 BCE. How do we know this? By running Planetarium software to determine whether there is a conjunction of the Sun and Tishya at 0 RA. Lo and behold there occurs such a conjunction in right ascension on May 14, **7414 BCE**.

It is expressly stated in the Vedāṅga Jyotiṣa in verse 6 of the Yajur Veda Recension that the Sun



and the Moon conjunct at Dhanishta during Vernal Equinox. There are 5 stars in the grouping δ Capricornus, Deneb Algeidi, α, β, γ, δ Delphini.

δ Capricorni *is the brightest star of all the choices and it has been argued by Prof Achar to be the better choice. In any event the range of dates for the VJ lays between 1330 BCE (β Delphini) and 1861 BCE (δ Capricorni)*

Sūryaprajnāpati and Kalalokaprakasha, Dakṣiṇāyana is heralded in the Pusya Nakṣatra. This indicates a dating of these Jain documents to 790 BCE, assuming Pusya is δ Cancri

The following key dates are found to be consistent with the sky inscriptions observed by Veda Vyāsa:
Kṛṣṇa's departure on Revati Sept. 26, 3067 (BCE
Kṛṣṇa's arrival in Hastinapura on Bharani Sept. 28, 3067 BCE
Solar eclipse on Jyeṣṭha Amāvāsyā Oct. 14, 3067 BCE
Krittika full Moon (lunar eclipse) September 29, 3067 BCE
War starts on November 22, 3067 BCE (Saturn in Rohiṇi, Jupiter in Revati)
Winter solstice, January 13, 3066 BCE
Bhishma expiry, January 17, 3066 BCE Magha Śukla Ashtami
A fierce comet at Puṣya October 3067 BCE
Balarāma sets off on pilgrimage on Sarasvati on Puṣya day Nov. 1, 3067 BCE
Balarāma returns from pilgrimage on Śrāvaṇa day Dec. 12, 3067 BCE
On the day Ghatotkacha was killed Moon rose at 2 a.m., Dec. 8, 3067 BCE

There are numerous instances of the knowledge in Calendrical Astronomy that we see in the MBH. A particularly famous and striking story is that which occurs at the end of the exile of the Pāndavas. As part of the consequence of their defeat in the gambling session, the Pandavas were required to live incognito in the 13th year, after their 12 year exile. Duryodhana attacks Virāta, who had given the Pandavas shelter and Arjuna, is compelled to fight against the Kauravas to support Virāta. Arjuna is recognized, and then there was a debate whether the 13th year was complete by then. Bhishma adjudicates and mentions that there are 2 Adhikamāsa's (intercalary months) in each 5 year span, , and he concludes that as a consequence there are 13 years, 5 months and 12 days have elapsed since the start of their exile. This indicates that here was a sophisticated knowledge of the calendar long before the date assigned to the Vedāńga Jyotiṣa."
Tilak "We need not therefore have any doubts about the authenticity of a work, which describes, this older system and gives rules for preparing a calendar accordingly, now this is what the VJ has done. It is a small treatise on the Vedic calendar, and though some of its verses are still unintelligible, yet we now know enough of the work to ascertain the nature of the calculations given therein" [171]*. It gives the following positions of the solstices and equinoxes. The last column is the estimated date of the equinoctial points per 72 years per degree from nearest point where an exact calculation was made. As we can see all the numbers are pretty consistent, considering these were naked eye observations and are within +125 to -125 of the mean.*

TABLE 5 ASTRONOMIC DATING OF KEY OBSERVATIONS IN THE MAHĀBHĀRATA		
	Description of Event	*Dating, Location Ujjain, India)*

[171] *Tilak, B "The Orion » , p.37-39*

	Sri Kṛṣṇa, on his final peace mission, set out for Hastinapura, when the Moon was at the asterism Revati.	*September 26, 3067 BCE, Sep 20. 3137*
	Kṛṣṇa arrived in Hastinapura when the Moon was at the asterism Bharani.	*September 28,3067, Sept 22, 3137*
	The lunar eclipse	*September 29, 3067 BCE*
	The solar eclipse at Jyeṣṭha	*October 14, 3067 BCE*
	The Great Bharata War	*November 22, 3067 BCE*
	Balarāma sits out the war and sets out for pilgrimage along the Sarasvati	*November 1, 3067 BCE*
	Balarāma returns from his pilgrimage, on the last day of the war	*Dec 12, 3067 BCE*
	The winter solstice occurred on	*January 13, 3066 BCE*
	Bhishma's expiry	*January 16, 3066 BCE*
	Birth and nirvana of Sri Kṛṣṇa (we have used 81 years as his lifespan but some traditions put his lifespan as 197 years) with a birthdate of July 21,3228 BCE	*3101 BCE to 3031 BCE*
	The comet Mahāghora appears at the asterism Puṣya	*October, 3066 BCE*
	Birth and Nirvana of Lord Buddha	*April 9, 1887 to March 27,1807 BCE*
	Birth and Nirvana of Adi Sankara	*April 5, 509 BCE*
	ŚakanripaKala, The Era of Kuru (Cyrus) of Persia	*550 BCE*
	Beginning of the Vikrama Era (Ṣukla pratipada)	*March 14, 57 BCE*
	Śālivāhana Śaka	*78 CE*

The great French astronomer and mathematician Pierre Simone de Laplace, did not dismiss the long periods of) the Great Ages (the Mahāyuga) as mere fancy. Rather he wrote ***'Nevertheless the ancient reputation of the Indian does not permit us to doubt that , they have always cultivated astronomy and the remarkable precision which they assign to the mean motions of the earth and the Sun and the Moon, necessarily required very ancient observations'***.

	TABLE 6 ASTRONOMICAL REFERENCES IN THE RĀMĀYAṆA	
	Event	Comments

	In the Bālakanda, it is said "Today the Magha star is in ascendance and in three days O mighty King, under the Uttara Phālguni star, thou should perform the nuptial ceremony'. This depicts, clearly that the sequence of stars was well known	
	The Puṣya star was regarded with a high distinction and is mentioned in the Ayodhya Kanda (AK, 2,12,4.2,4.21) and the Yuddha Kanda (YK, 126.54)	
	In the AK (41.11) all the planets are said to come together when Rama, Sita, and Lakshmana were departing from Ayodhya for exile. This was an omen portending the battle for Lanka)	
	The AK (80,17) tells us that auspicious planets and hours were considered even in establishing the camp of Bharata	
	The AK (89,17) mentions Maitra Muhurta, which is not very prevalent today	
	Jatāyu observes in the AK (68,12) that 'The hour during which Ravana bore away Sita is called Vinda and the loser soon recovers that which is lost in this hour	
	Rohiṇi is mentioned in the Sundara Kānda (SK,17,24,1.,9) and the YK (92.45,102.32)	
	Planets Mars and Mercury find their mention in the YK (54,28)	
	The Panchami Tithi has been mentioned in the UK (100,20)	
	Saumya (the planet Mercury has been mentioned in the UK (100.20)	

"The greatest benefit of the astronomical sciences is to have dissipated errors borne of ignorance of our true relations with nature, errors all the more fatal, since their social order must rest solely on these relations. Truth and justice are its immutable basis. Far be it for us to rationalize the dangerous maxim that it may sometime be useful to deceive or to enslave men the better to insure their happiness".

Despite such lofty sentiments, the record of the Occidental of adhering to the truth has not been spectacular, especially when it comes to hiding the source of his knowledge in the 16th century.

In this chapter we have shown that the results of Astro-chronology are pretty consistent in dating the RV to a date approximately in the 5th millennium, prior to the Common Era and that the Vedāńga Jyotiṣa can be dated to the middle of the 2nd Millennium. The Occidental must come up with a more valid reasoning than merely to say that he does not believe in astronomical dating.

TABLE 7 CARDINAL POINTS DURING VEDĀṄGA JYOTIṢA ERA		
Winter Solstice in Beginning of Sravishta (Dhanishta)	293^{o} 20’	1440 BCE
Vernal Equinox in 10^{o} of Bharani	23^{o} 20’	1410 BCE
Summer Solstice in middle of Āśleṣā	113^{o} 20’	1350 BCE
Autumnal Equinox in 3^{o} 20’ of Vi śākhā,	203^{o} 20’	1600 BCE

CHAPTER VIII
ASTRONOMY OF THE ANCIENTS

QUOTE FROM GEMINUS, GREEK ASTRONOMER IN ODYSSEY;

"*Now reckoning the years according to the Sun means performing the same sacrifice to the Gods at the same seasons in the year, that is to say, performing the spring sacrifice always in the spring, the summer sacrifice in the summer and similarly offering the same sacrifices from year to year, reckoning the days according to the moon means contriving that the names of the days of the month shall follow the phases of the moon*."

If one were to read the above passage without knowledge of its source, one would make the presumption that the passage was from the Veda or one of its Appendices either in the Brāhmaṇa or in one of the Srauta Sūtras of the Vedāńga, it is quite clear that there is a common paradigm highlighted by references to sacrifices. This common heritage manifests itself in many ways, for example in the naming of the Gods (Zeus, dyaus, Jupiter, Dyaus Pitr). There is general agreement that at some point in the distant past there was a common heritage. But there the agreement ends in an ignominious manner. There is increasing evidence that that there was a steady but substantial migration over several thousands of years out of India (Druids, Persians, Greeks). The Romany Gypsies are the most recent version of such a migration, if one were to ignore the 35 million Diaspora that has dispersed during the last 2 centuries. The connections between Ancient Greece and India are carefully elaborated and listed by Pockocke. In our view it is quite possible and even probable, that Indic approach to astronomy was propagated by these ancient Indics. Alas, we do not have the luxury of being quite as categorical as the David Pingree's of this world.

We know now, as a consequence of the work of Kepler, that the orbits of the planets are ellipses with the Sun at one of the foci of the ellipse. The ellipticity of the orbit is expressed by a quantity called the Eccentricity $\boldsymbol{e}$, which is a measure of the extent of the deviation from circularity of the orbit or the extent to which the orbit is flattened to look more like an egg. It may be shown that the Eccentricity scales linearly with $\boldsymbol{e}$, whereas the 'egginess' of the ellipse scales with $\boldsymbol{e}^2$. Since the eccentricities of the planets in solar orbit are all relatively small (e <.21) it follows that one can ignore the departure from circularity and retain the Eccentricity and use eccentric circles for orbits to obtain a first approximation. This is exactly what happened. The Indics as well as the Greeks used eccentric circles, without realizing that there was a rationale behind this approximation to the true orbits. There are however fundamental and significant differences in approach which cannot be wished away in the rush to judgment to classify the Indic approach as a corollary to the Greek effort and making the developments in India sequential to that of the Greeks and Babylonians. Our approach is to assume that the Indic effort is relatively independent of the developments in Babylonia (and Greece and then look for synchronisms in dates to see if there was a transmission in either direction).

KEPLER'S MODEL

We present below the modern approach to the simplest model in planetary astronomy, as a basis for comparison. As the criteria for accuracy we will use the equation of the center and the true longitudes of planets to compare results, and finally we will examine the causes for the differences in the assumptions made by the Greeks to account for the difference

TABLE 1 NEWTON INVERSE SQUARE LAW & KEPLER'S LAWS can be summarized as follows
I **Inverse Square Law** The orbit of a Planet around the Sun is given by an ellipse *r = a (1- e cos v)* . This is a solution to the differential equation for the ellipse $\frac{d^2}{dt^2}\boldsymbol{r} - r(\frac{d\boldsymbol{\Theta}}{dt})^2 = \frac{\boldsymbol{\mu}}{\boldsymbol{r}^2}$
II The areal velocity Law ***1/2(r² dΘ/ dt***) is constant = h. The radius vector connecting the planets to the sun sweeps out equal areas in equal time
III the square of the period of revolution of each planet is proportional to the cube of the semi-major axis of the planet's orbit **(harmonic law).** $\boldsymbol{T^2}$ is proportional to $\boldsymbol{a^3}$**.**

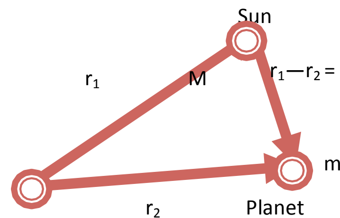
Johannes Kepler published his first two laws in 1609, having found them by analyzing the astronomical observations of Tycho Brahe. Kepler did not discover his third law until many years later, and it was published in 1619. Kepler's laws assume a heliocentric solar planetary system, but as we have already demonstrated, the 2 systems are equivalent for small values of the Eccentricity ***e.*** *So that we can use Keplers model as an approximation of reality, albeit a more rational and we expect the resulting approximation to be more accurate and valid over a wider range of parameters than the Geocentric models.*

ELLIPTIC ORBITS AND EQUATIONS OF CENTER

The goal of all the computations is to arrive at the positions of the sun and the other planets with respect to a geocentric coordinate system. The starting point for the modern theory is the application of Kepler's laws. Kepler's aim is not substantially different from that of the author of the Almagest. He intends to give a description of the Kinematics of the Solar system without concerning himself as to the causes of such a motion. It is the genius of Isaac Newton that he realized the Inverse square law of attraction between celestial bodies would give an orbital path that would satisfy Kepler's Laws.

KEPLER'S MODEL

FIGURE 1
NEWTONS INVERSE SQUARE LAW



The Problem is to determine an explicit relation between the true Anomalies of the orbital body (Earth) in terms of known quantities
e is the Eccentricity of the orbit
P is the Planet whose orbit we are studying

The Equations of motion for the Sun and the Planet are

$$m_e \frac{d^2\boldsymbol{r}_2}{dt^2} = \frac{-G\boldsymbol{m_s m_e}}{\boldsymbol{r^3}} \, (\boldsymbol{r}_2 - \boldsymbol{r}_1) \quad \text{……………………………………………………………………………} \quad (1)$$

$$m_s \frac{d^2\boldsymbol{r}_1}{dt^2} = \frac{G\boldsymbol{m_s m_e}}{\boldsymbol{r^3}} \, (\boldsymbol{r}_2 - \boldsymbol{r}_1) \quad \text{……………………………………………………………} \quad (2)$$

$m_s \frac{d^2r}{dt^2} = \frac{-\mu}{r^3}\ r$ ……………………………………………………………………………….(3)

Where m_s = Mass of Sun, m_e = mass of the earth or planet
G = Gravitational constant
And μ = $G(m_s+m_e)$, …………………………………………..……………… (4)
where $r = r_2 - r_1$
it can be shown from (3) that

$\frac{d(r\times \acute{r})}{dt} = 0$ …………………………………………………………….. (5)

where ŕ refers to the time derivative of r, the velocity vector.

Also the radial component of Eqn. 3 gives

$\frac{d^2r}{dt^2} - r(\frac{d\theta}{dt})^2 = \frac{\mu}{r^2}$ …………………………………………………………………………………….. (6)

And the tangential component

$r\,\ddot{\theta} + 2\left(\dot{r}\dot{\theta}\right) = 0$. This implies that the motion of the planet is in a plane and that the areal velocity (the area swept by the radial line connecting the Sun and the planet per unit time)is a constant. In polar coordinates

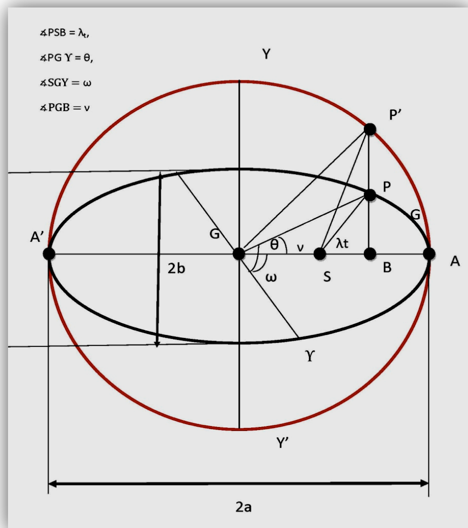
$\frac{1}{2}(r\times\frac{dr}{dt}) = \frac{1}{2}(r^2\frac{d\theta}{dt})$ = constant= h ……………………………………………………………… (7)

Using eqn.6 to eliminate θ we get

$\frac{d^2r}{dt^2} - \frac{4h^2}{r^3} = \frac{-\mu}{r^2}$ ……………………………………………………………………… (8)

The solution of this second order differential equation is

$r = \frac{1}{1-ecosv}$ ………………………………………………………………………………………… (9)



APA is the elliptical orbit of a planet and S is the focus with the attracting force. The revolution of the planet begins from one of the Apses (A the Perihelion, and A' the Aphelion), the planet travels n radians per unit time (1 day). ASP is Manda Kendra= λ_t
r, Θ= polar coordinates,

LEGEND FOR FIGURE 2

- λ_t = true anomaly = **∡ASP =Manda Kendra**
- λ_m = mean anomaly = ∡AGP = dn = $\frac{2\pi\,(t-t_*)}{\tau}$ = Madhyama Manda Kendra
- e = Eccentricity

FIGURE 2 KEPLER'S MODEL

- ω = Angular distance from designated origin (e.g.point of zero right ascension}, and axis
- θ = Angular coordinate of planet from designated origin (e.g. point of zero right ascension,]
- τ =Orbital period of planet
- t = time corresponding to the position of the planet at P

- t_s = starting time
- $t – t_s$ = time elapsed since commencement

- After *d* days the planet is at location P, where ∡***ASP = λ_t*** gives the true anomaly
- We define a circle around the major axis of the ellipse, with diameter equal to the major axis a, the ⊥**r** to AA' meets the ellipse at **P. Then**
- **∡AGP' = ν = $\theta - \omega$** is called the eccentric or elliptic anomaly = **angular distance,** with Sun at the Focus from the Perihelion A to the planet. The angle is measured at the geometric center of the ellipse =
- **∡AGP = λ_m** is the mean anomaly
- ***GC*** = semi minor axis = $b = a\,(1 - e^2)^{0.5}$

- The length **SP** = r, represents the radial distance of the planet from the sun.
- The equation of the ellipse is $\frac{x^2}{a^2}+\frac{y^2}{b^2} = 1$ ……………………………………………........ (10)
- The equation of the circle is a special case of the ellipse
- $\frac{x'^2}{a^2}+\frac{y'^2}{a^2}$ = 1, ...(11)
- If x = x' then $\frac{y}{y'} = \frac{b}{a}$ = BP/BP'..(12) and (13)
- And
- SB = r cos λ_t, BP = r sin λ_t, GB = a cos λ_m, BP'= a sin λ_m, and GS = ea,

TABLE 2 MINI-GLOSSARY OF SANSKRIT TERMS (THESE CAN BE FOUND IN THE MAIN GLOSSARY ALSO (APPENDIX A)
Manda samskāra – manda correction for obtaining the equation of the center
Kaksyamandala – circumference of deferent circle = 2πR
Madhyamagraha – mean planet λ_m
Madhyama Mandakendra – mean anomaly λ_m
Mandocca- apogee ω
Mandakendrajya – R sin $\lambda_{m,}$ the distance
Mandaphala – Equation of Center
Mandasphutagraha – the planet corrected for the equation of the center θ_{ms}
Graha Brāhmaṇa Vrtta – center of the orbital circle of the Planet, center of the epicycle
Mandocca nicha vrtta – epicycle of the exterior planet (also called manda circle)
Pratimandala – the orbital circle of the eccentric (deferent)

Eqn.13 yields

- r sin $\lambda_t = b \sin \lambda_m = a\,(1 - e^2)$1/2sin λ_m..(14)
- since SB = GB – GS, we have r cos λ_t = a (cos λ_m – e)..(15)
- Taking the square root of the sum of the squares
- SP = r = a (1- e cos λ_m) .... (16)
- This is the Heliocentric distance of the planet Manda Karṇa
-
- $\frac{Area\ ASP}{Area\ of\ ellipse} = \frac{d}{Time\ of\ revolution}$ = d/$\frac{2\pi}{n} = \frac{dn}{2\pi}$..(17)
- $\frac{Area\ ASP}{Area\ AGP'} = \frac{Area\ of\ ellipse}{Area\ of\ circle} = \frac{\pi ab}{\pi a^2} = \frac{b}{a}$...(18)
-
- $\frac{Area\ ASP}{Area\ of\ ellipse} = \frac{Area\ AGP'}{\pi a^2}$.. (19)
- area ASP = area SPB+ area ABP = $\frac{r^2 \cos\ \lambda_t \sin \lambda_t}{2}$ +area AB...(20)
- area ABP = $\frac{b}{a}$ area ABP' ....(21)
- area ABP' = area AGP' – area GP'B = $\frac{1}{2}\boldsymbol{v}a^2 - \frac{1}{2}a^2$ (cos$\boldsymbol{v}$ sin)...(22)
- $\frac{dn}{2\pi}(\pi ab) = \frac{r^2 \cos\ \lambda_t \sin \lambda_t}{2} + \frac{b}{a}\frac{a^2}{2}$ ($\boldsymbol{v}$ - cos$\boldsymbol{v}$ sin $\boldsymbol{v}$)...(23)
-
- $\frac{Area\ AGP'}{Area\ of\ circle} = \frac{a^2}{2}$ (v – eSin v)/(πa²)...(24)
- dn = λ_m= v – eSin v..(25)
- is called the mean anomaly. Recall that r = a(1- e cos v) ....,,,,,,,,,,,.............................(7)
- so we have solving for λ_m = v – eSin v ....(26)
- cos $\lambda_t = \frac{\cos v - e}{1 - e \cos v}$ ....(2)

POSITION AS A FUNCTION OF TIME

Kepler used these three laws for computing the position of a planet as a function of time. His method involves the solution of a transcendental equation called Kepler's equation. The procedure for calculating the heliocentric polar coordinates (r, θ) to a planetary position as a function of the time t since perihelion, and the orbital period P, is the following four steps.

1. Compute the **mean anomaly λ_m** from the formula

$\lambda_m = \frac{2\pi\,(t - t_s)}{\tau}$

2. Compute the **eccentric anomaly *v*** by solving Kepler's equation:

$\lambda_m = v - e \sin v$

3. Compute the **true anomaly** $\lambda_t$by the equation:

Tan $\frac{\lambda_t}{2} = \sqrt{\frac{1+e}{1-e}}$Tan $\frac{v}{2}$

4. Compute the **heliocentric distance** *r* from the first law:

r = $\frac{p}{1 + e \cos \lambda_t}$

The important special case of circular orbit, ε = 0, gives simply $\lambda_t = \boldsymbol{v} = \boldsymbol{\lambda_m}$ The proof of this procedure is shown below.

Please see figure 1 which shows the Geometric construction for Kepler's calculation of λ_t . The Sun (located at the focus) is labeled *S* and the planet P is in orbit around the sun. The auxiliary circle is an aid to calculation. Line *BP'* is perpendicular to the base and through the planet *P*. The shaded sectors are arranged to have equal areas by positioning of point *y*.

The Keplerian problem assumes an elliptical orbit and the four points:
s the Sun (at one focus of ellipse);
z the perihelion
c the center of the ellipse
p the planet

It turns out that the earth and the five visible planets all possess low Eccentricity orbits characterized by e << 1. Hence it is a good idea to expand these equations in terms of a power series with e as a parameter and neglect the higher order terms.

$\lambda_t = \nu + \text{e} \sin \nu + (1/4)\, \text{e}^2 \sin 2\nu$

$\text{r} = \text{a}(1 - \cos \lambda_t - e^2 sin^2 \lambda_t)$

$\nu = \lambda_m + e \sin \lambda_m + \frac{1}{2} e^2 \text{Sin } 2\lambda_m$

$\text{r} = \text{a}(1 - \text{e} \cos \text{v} - \text{e}^2 \sin^2 \text{v})$

$\boldsymbol{\lambda_t} = \boldsymbol{\lambda_m} + 2\text{e} \sin \boldsymbol{\lambda_m} + (5/4)\, \text{e}^2 \sin 2\boldsymbol{\lambda_m}$ ……………………………………………..................(28)

These equations can be combined to give explicit functions of r and λ_t. The general approach to finding the location of a planet is doing it in 2 steps. The position of the planet in its elliptical orbit with the sun as one of its foci is determined. The position of the earth relative to the sun is then calculated. These equations would give the results based on a Keplerian Model, a heliocentric model, without resorting to approximations regarding the Eccentricity of the ellipse

TABLE 3 COMPARATIVE TIMELINE OF ASTRONOMY OF THE ANCIENTS

Date	The Indics	Greco Babylonian	Chinese
	7000-4000 BCE The Vedic era. observation + inference, 6 year yuga, with intercalation repeated every 40 years. see discussion in this Chapter and in chapter III 2000 BCE Yajnavalkya (see chapter on Indic Savants) Garga (Chapter XI on Indic savants) Parasara (see Chapter 11 on Indic savants)	8000 BCE River Valley civilization in Navalli Cori 2637 BCE Sumer 2000 BCE Akkad Reign of Hammurabi Enuma Elish Observation of Venus is indicated	2637 BCE., the legendary First Emperor Huan Ti (the "Yellow Emperor") instituted the calendar that survives in China to this day for festival dates. The calendar has lunar months but the seasons are determined by the position of the stars. Like the calendars developed in ancient Mesopotamia, a regular year has 12 lunar months and an intercalary leap year has 13 lunar months. This is therefore a Luni-solar calendar,
2000 BCE	Baudhāyana(see chapter on Indic savants)	The civilization of Karduniash -Kassites	1299 BCE Oracle Bones from Shang Dynasty, imply a synodic month of 29.5 days and a year of **365.25**^{d}. Divide the ecliptic into 28 regions for purposes of recognition of stars. The objective does not appear to be the same. Stars are generally nearer to the celestial equator than they are to the ecliptic as in t**he** Indian case. see chapter
2000 BCE **1400 BCE-**	Āpastamba(see chapter on Indic savants)	Enuma Anu Enlil. There is evidence that the Kassites were of Indic origin	

1800-1350 BCE	Vedāńga Jyotiṣa by Lagadha. Concept of a Tithi defined and the Nakṣatra system is well established. See entries in Table 2 of chapter III		
700 BCE – 200 BCE	Sūrya Prajnāpati, there is a 17.3^{o} difference in longitudes between the time of Lagadha and that of Sūryaprajnāpati, indicating a time lapse of 1200 year	Nebuchadnezzar - record of eclipses 800 BCE, Ashur Bani Pal , the Assyrians, 700 BCE Mulapin , end of Assyrian empire. becomes province of Persia	776 BCE Record of 900 solar eclipses and 600 lunar eclipses over the next 2000 years
600 BCE	Maya Asura, Sūrya Siddhānta, The Surya Siddhānta is the first treatise in the world that gives a comprehensive view of Astronomy, as it was practised.	Chaldean Dynasty 600 BCE astronomical diaries. Thales of Miletus	466 BCE Observed Haley's comet
500-100 BCE	Sakanripa Kala. Kuru of the Akshamanish dynasty of ancient Iran controls briefly a portion of the Northwest of India	Seleucid dynasty (after Alexander). Eudoxus, Eratosthenes, Hipparchus	Planetary periods determined Mars 780.5, Mercury 115.9, Venus 584.1 Established the 19 year, 235 synodic months equivalence before Meton
100 BCE 180 CE Vikram Era Salivahana Era		Claudius Ptolemy (see chapter on Knowledge transmission for details	Use of Armillary sphere to study the motion of stars. Use of 12 sign zodiac introduced by Buddhist monks Established the 76 year ,840 month cycle, before Kallipos
3xx CE **600** **Āryabhaṭa(see chapter on Indic savants)**			Recognition of precession in China. Determine tropical year 365.242815, sidereal year **365.257612^{d}**. Inequality of seasons discovered.
Varāhamihīra (see chapter on Indic savants)			
628 CE Brahmagupta (see chapter on Indic savants), 930 Manjula, **1150 CE Bhāskara II (see chapter on Indic savants)** **1380 CE Mādhava (see chapter on Indic savants)** **1430 CE Parameswara (see chapter on Indic savants)** **1500 CE Nīlakaṇṭa proposes semi - heliocentric theory, which is later called the Tychonic theory(see chapter on Indic savants)** **1530 Jyeṣţhadeva authors the GaṇitaYuktibhāṣā[172] (see chapter on Indic savants).** **1530-1560 (Jesuits sent a posse of 60 – 90 to ferret out Indic mathematics, navigation, and astronomy. It is suspected that the Jesuits learned the craft from Sankar Variyar the student of Nīlakanta** **1575 Achyuta Pisārati see chapter on Indic savants) Tycho Brahe.**			

[172] *Ganita-Yuktibhāşa by Jyeşţhadeva, Malayalam text critically edited by KV Sarma. Explanatory notes by K Ramasubramanian, MD Srinivas, MS Sriram, Published by Hindustan Book agency, 2008*

BABYLONIAN CHRONOLOGY AND HISTORY

We quote the following from a well-known site on Babylonian History; http://history-world.org/assyria%20part%20two.htm

"*An essential condition for adequate knowledge of an ancient people is the possession of a continuous historical tradition in the form of oral or written records. This, however, in spite of the mass of contemporaneous documents of almost every sort, which the spade of the excavator has unearthed and the skill of the scholar deciphered, is not available for scientific study of Babylonian or Assyrian antiquity. From the far-off morning of the beginnings of the two peoples to their fall, no historians appeared to gather up the memorials of their past, to narrate and preserve the annals of these empires, to hand down their achievements to later days. Consequently, where contemporaneous records fail, huge gaps occur in the course of historical development, to be bridged over only partially by the combination of a few facts with more or less ingenious inferences or conjectures. Sometimes what has been preserved from a particular age reveals clearly enough the artistic or religious elements of its life, but offers only vague hints of its political activity and progress. The true perspective of the several periods is sometimes lost, as when really critical epochs in the history of these peoples are dwarfed and distorted by a lack of sources of knowledge, while others, less significant, but plentifully stocked with a variety of available material, bulk large and assume an altogether unwarranted prominence. "*

The first group of Akkadian speaking people settled initially in Babylon and later in Assyria, on the Tigris, approximately at the end of the third millennium BCE. They were preceded by the Sumerians in the fifth or early fourth millennium. They developed a style of writing in wedge shaped (cuneiform) symbols on wet clay tablets which were subsequently hardened by sun drying or baking. The Sumerians may have been the first to notice the distinction between the 'wanderers' (Greek planetoid) and the fixed stars.

Even the later historians of antiquity failed to provide the information necessary to fill in the gaps. The three books of Babylonian or Chaldean History, by Berosus, have come down from the past only in scanty excerpts of later historians. Berosus was a Babylonian priest of the god Bel, and wrote his work for the Macedonian ruler of Babylonia, Antiochus Soter, about 280 BCE. As the cuneiform writing was still employed, he must have been able to use the original documents, and could have supplied just the needed data for our knowledge. Still, the passages preserved indicate that he had no proper conception of his task, since he filled a large part of his book with mythical stories of creation and incredible tales of primitive history, with its pre-diluvian dynasties of hundreds of thousands of years. A post-diluvian dynasty of thirty-four thousand ninety-one years prepares the way for five dynasties, reaching to Nabuchednassar, and king of Babylon (747 BCE), from whose time the course of events seems to have been told in greater detail down to the writer's own days.

Imperfect and crude as this work must have been, it was by far the most trustworthy, and important compendious account of Babylonio-Assyrian history furnished by an ancient author, and for that reason would, even to-day, be highly valued. A still more useful contribution to the chronological framework of history was made by Ptolemy, a geographer and astronomer of the time of the Roman Emperor, Antoninus Pius. Ptolemy's "Canon of Kings," compiled for time Berosus begins to expand his history, and continues with the names and regnal years of the Babylonian kings to the fall of Babylon. Since Ptolemy proceeds with the list through the Persian, Macedonian, and Roman regnal lines in continuous succession, and connects the era of Nabonassar with those of Philip Arridaeus and Augustus, a synchronism with dates of the Christian era is established, by which the reign of Nabonassar can be fixed at 747-733 BCE and the reigns of his successors similarly stated in terms of our chronology. By this means, not only is a chronological basis of special value laid for this later age of Babylonian history, but a starting- point is given for working backward into the earlier periods, provided that adequate data can be secured from other sources.

TABLE 4 VERY BRIEF BABYLONIAN TIMELINE	
Reign of Hammurabi	1728 BC – 1686 BCE
Enuma Elish	1700 BCE
Observation of Venus is indicated	
Kassite Dynasty	1500 – 1200 BCE
Enuma Anu Enlil	
Nabuchednassar - record of eclipses	800 BCE
Ashur bani Pal , the Assyrians,	700 BCE
Mulapin Chaldean Dynasty astronomical diaries the beginning of mathematical astronomy	600 BCE
Equal Sign Zodiac – regularization of Calendar	500 BCE
Persian Rule	500 BCE
Seleucid dynasty (after Alexander)Planetary	300 BCE

TABLE 5 PLANETARY ORBITAL DATA

Planet	Sidereal Period in years	Mass, earth =1	Eccentricity of orbit	Inclination to ecliptic in degrees	Mean distance from sun ,AU	oblateness
Mercury	.24	.06	.2056	7.00	0.387	0
Venus	.62	.86	.0068	3.39	.723	0
Earth	1	1.00	.0167	0	1	.0034
Mars	1.88	.11	.0934	1.85	1.524	.0059
Jupiter	11.87	317.83	.0484	1.31	5.203	.065
Saturn	29.46	95.16	.0557	2.48	9.537	.098
Uranus	84.01	14.54	.0472	0.77	19.191	.023
Neptune	164.8	17.15	.0086	1.77	30.069	.017
Pluto	247.6	0.0022	.2486	17.14	39.482	0

The original documents of Babylonia and Assyria are unexpectedly rich from 760 BCE to about 650 BCE. Sometimes to the mere name of the limu was added a brief remark as to some event of his year.

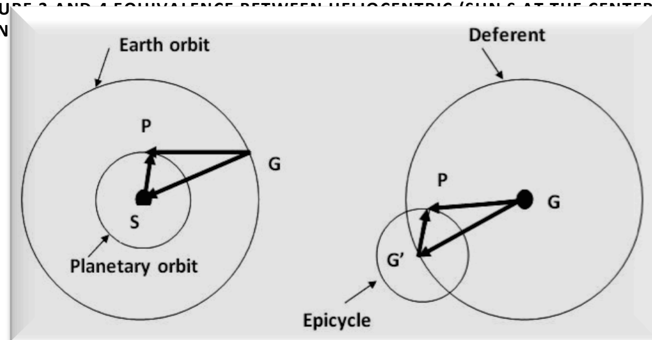
Sagali in the reign of Ashurdan III., has been calculated to have taken place on the fifteenth of June, 763 BCE, a fact which at once fixes the dates for the whole list and enables its data to be compared with those derived from the synchronisms of the canon of Ptolemy and other sources. The result confirms the accuracy of the Assyrian document, and affords a trustworthy chronological basis for fully three centuries of Assyrian history. For the earlier period before 900 BCE the ground is more uncertain, but the genealogical and chronological statements of the royal inscriptions, coupled with references to contemporaneous Babylonian kings whose dates are calculable from native sources, supply a foundation which, if lacking in some parts, is yet capable of supporting the structure.We have to wait till we get to about 700 BCE for the first systematic observations in astronomy, which is well after the Vedāńga Jyotiṣa period in ancient India, by which period the fundamental concepts of Indic astronomy were well in place

in India . It is difficult to reconcile the popular assumption in the west that India was indebted to Babylon for the sexagesimal arithmetic with this chronology. Clearly sexagesimals were in use in India before this date.

There is as yet no clear distinction made between astronomic observations and meteorological phenomena in Babylon. Ptolemy claims that eclipse records were available from the time of Nabonassar (736 BCE). It is the guess of Neugebauer that a quantitative mathematical astronomy did not develop before 500 BCE. Up to about 480 BCE there is no regularity in the intercalations of their Lunisolar calendar, but a hundred years later the rule of 7 intercalations in 19 years appears to be prevalent . The existence of a lunisolar calendar presupposes the knowledge of a relationship between m Lunar months and n Solar months, as we have explained in Chapter 2, where the case of m=235 and n= 19 is dealt with

The legacy of Babylon like other ancient civilizations is significant. That does not mean however that they preceded the Indics in every branch known to mankind, and certainly there is little or no evidence that the Indics borrowed anything from the Babylonians. There is no Babylonian or Greek text that can be claimed to be a progenitor of a Sanskrit translation. The chronology of the Indics when juxtaposed against that of the Babylonians precludes such an eventuality. More work needs to be done to establish the connections between Babylon and India, but the present state of knowledge is insufficient to state categorically that there was any transmission. Such an investigation must include the possibility of a transmission to Babylon. But, most Occidental Historians insist without any documentary evidence, that the following were transmitted to India from either Babylon or Pre Ptolemaic Greece,

FIGURE 3 AND 4 EQUIVALENCE BETWEEN HELIOCENTRIC (SUN S AT THE CENTER) AN



The sexagesimal system of numbering

1. Values for a variety of astronomical constants, such as the length of the lunar month
2. Period relations such as the 18 year Saros cycle of lunar eclipses
3. The 3:2 ratio of longest to shortest daylight of Babylon
4. A scheme for calculating times for the rising of zodiacal signs
5. Use of Epicycles and Equants in Planetary models
6. Trigonometry and the Sine Table
7. Observational data pertinent to the above
8. Pingree insisted that the zero and the decimal place value system trudged into India on the backs of anonymous but highly talented Greek astronomers.

GREEK ASTRONOMY

Greek Astronomy – Most documents have been lost. All that is left to future generations are Euclid's Elements and Ptolemy's Syntaxis. As we shall see the dating of either of these is fraught with too many

hypotheses masquerading at best as leaps of inference. It is almost certain that these books are of much later vintage than is claimed for them. Both of these figures are purported to be Alexandrian. It is intuitively apparent that Ptolemaic epicyclic model on the right consisting of a deferent and an epicycle and for the case of an inferior planet P shown here (for circular orbits) are completely equivalent to a heliocentric model G represents the location of the earth in orbit around the sun. The approximation is to the first order terms in e.

Figures 5 and 7 illustrate the analogy between the Heliocentric and Geocentric Models in the case of an inferior planet i.e. a planet that is closer to the Sun than the earth (Venus, Mercury)

FIGURE 5 HELIOCENTRIC MODEL FOR INFERIOR PLANET

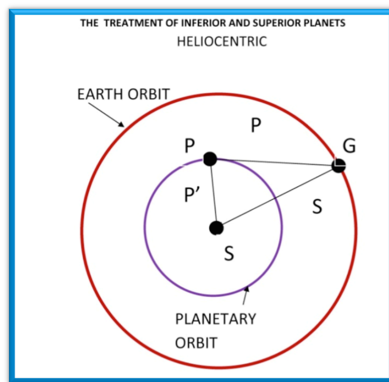
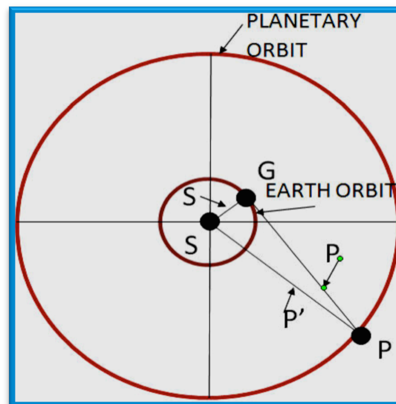


FIGURE 6 HELIOCENTRIC MODEL FOR A SUPERIOR PLANET



S is the location of the Sun
P is the location of the planet
G is the centre of the earth
P' is the Sun planet displacement vector or the radius vector of the orbit of the Planet around the Sun.
The vector S (GS) is the radius vector of the orbit of the earth around the sun. The vector P is the Planet earth displacement vector or the geocentric radius of the Planet when seen from the earth , is then the sum of S and P'. In the geocentric case, S gives the displacement of the Guide Point G' from the earth. Since S is also the displacement of the Sun from the earth, G, it is clear that G' is executing a Keplerian173 orbit around the Earth whose elements 174 are the same as those of the apparent]

[173] *See chapter 8, elliptical orbits and equations of center*
[174] *To review the elements of an orbit, see Chapter 1. Element of an orbit , Figure 19*

FIGURE 7 GEOCENTRIC MODEL FOR AN INFERIOR PLANET

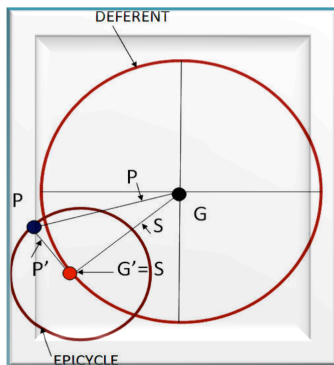
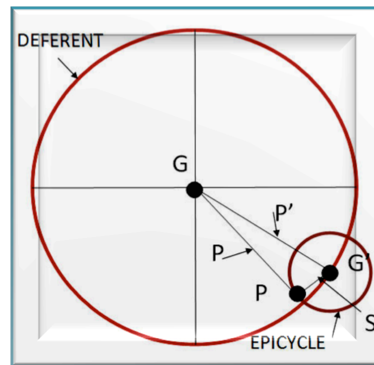


FIGURE 8 GEOCENTRIC MODEL FOR A SUPERIOR PLANET



orbit of the Sun around the earth. This implies that the Sun is coincident with G' and the ellipse traced out by G' is known as the Deferent in Ptolemaic astronomy175 . . The vector P' is gives the displacement of the planet P, from the guide point G'. Since P' is also the displacement of the planet P from the sun S, it follows that P' executes a Keplerian orbit around the guide point G', whose elements are the same as those of the orbit of the planet around the Sun. The ellipse traced out by P about G' is termed the Epicycle.

To summarize for the Interior planets, The Deferent represents the earth orbit and the Epicycle represents the orbit of the planet around the Sun We can do a similar analysis for the Superior planets (Mars, Jupiter, and Saturn). It turns out that there is one crucial difference for the Interior planets. The deferent in the case of the superior planets is the orbit of the planet and the epicycle is the earth orbit around the sun or to be more precise the apparent orbit of the sun around the earth. The Key principle here is that the order in which we place the planetary orbit and the earth orbit (in the geocentric case it is the Sun's orbit around the earth) is immaterial at least to a first order of approximation. This is a principle that Nīlakaṇṭa uses to rationalize the Geocentric Models into 1 model where the planets are rotating around the Sun while the Sun is orbiting the Earth. This is also the so called Tychonic Model, which was developed by Nīlakaṇṭa at least 100 years prior to Tycho Brahe. We will refer to this model as the Nilakanta-Tycho Model.

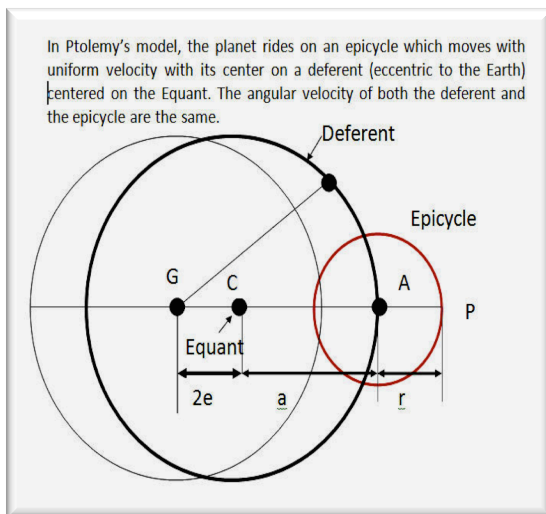


FIGURE 9 THE PTOLEMAIC MODEL

[175] *See Greek astronomy in Chapter 8*

WHAT ERRORS DID PTOLEMY MAKE?

PTOLEMY'S ERRORS

By R. Fitzpatrick, professor of Physics, University of Texas at Austin Ptolemy's first error lies in his model of the sun's apparent motion around the earth, which he inherited from Hipparchus. Figures 11, 10 show what Ptolemy actually did, in this respect, compared to what he should have done, in order to be completely consistent with the rest of his model. Let us normalize the mean radius of the sun's apparent orbit to unity, for the sake of clarity. Ptolemy should have adopted the model shown on the left in Fig. 10, in which the earth is displaced from the center of the sun's orbit a distance e = 0.0167 (the Eccentricity of the earth's Orbit around the sun) towards the perigee (the point of the sun's closest approach to the earth), and the Equant is displaced the same distance in the opposite direction. The instantaneous position of the sun is then obtained by allowing the radius vector connecting the Equant to the sun (SQ) to rotate uniformly at the sun's mean angular velocity. Of course, this implies that the sun rotates non-uniformly about the geometric center of the orbit. Ptolemy actually adopted the model shown on the right in Fig. 11. In this model, the earth is displaced a distance 2e from the center of the sun's orbit in the direction of the perigee, and the sun rotates at a uniform rate (i.e., the radius vector CS rotates uniformly). It turns out that, to the first-order in e, these two models are equivalent. Hence, the error [which is of the order of (e2)] is small. Nevertheless, Ptolemy's model is incorrect, since it implies too large a variation in the angular size of the sun during the course of a year. Ptolemy presumably adopted the latter model, rather than the former, because his Aristotelian leanings prejudiced him in favor of uniform circular motion whenever this was consistent with observations. (Note that Ptolemy was not particularly interested in explaining the relatively small variations in the angular size of the sun during the year—presumably, because this effect was difficult for him to accurately measure.)

Ptolemy's next error was to neglect the non-uniform rotation of the superior planets on their epicycles. This is equivalent to neglecting the orbital Eccentricity of the earth (recall that the epicycles of the superior planets actually Represents the earth's orbit, see Figure 9) compared to

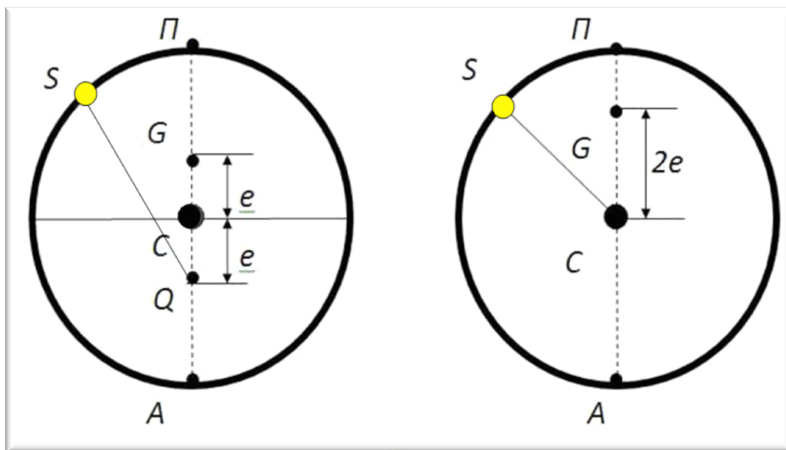


FIGURE 10 (CORRECT), 11(INCORRECT): PTOLEMY'S MODEL OF THE SUN'S APPARENT ORBIT (RIGHT) COMPARED TO THE CORRECT MODEL (LEFT). THE RADIUS VECTORS (SQ IN FIGURE 10 AND SC IN FIGURE 11) ROTATE UNIFORMLY. HERE, S IS THE SUN, G THE EARTH, C THE GEOMETRIC CENTRE OF THE ORBIT, Q THE EQUANT, Π THE PERIGEE, AND A THE APOGEE. THE RADIUS OF THE ORBIT IS NORMALIZED TO UNITY.

those of the superior planets .It turns out that this is a fairly good approximation, since the superior planets all have significant greater orbital eccentricities than the earth. Nevertheless, neglecting the non-uniform rotation of the superior planets on their epicycles has the unfortunate effect of obscuring the tight coupling between the apparent motions of these planets, and that of the sun. The radius vectors connecting the epicycle centers of the superior planets to the planets themselves should always all point exactly in the same direction as that of the sun relative to the earth. When the aforementioned non-uniform rotation is neglected, the radius vectors instead point in the direction of the mean sun relative to the earth. The mean sun is a fictitious body which has the same apparent orbit around the earth as the real sun, but which circles the earth at a uniform rate. The mean sun only coincides with the real sun twice a year at the equinoxes.

Ptolemy's third error is associated with his treatment of the interior planets. As we have seen, in going from the superior to the interior planets, deferents and epicycles effectively swap roles. For instance, it is the deferents of the interior planets, rather than the epicycles, which represent the earth's orbit. Hence, for the sake of consistency with his treatment of the superior planets, Ptolemy should have neglected the non-uniform rotation of the epicycle centers around the deferents of the interior planets, and retained the non-uniform rotation of the planets themselves around the epicycle centers. Instead, he did exactly the opposite.
This is equivalent to neglecting the interior planets' orbital eccentricities relative to that of the earth. It follows that this approximation only works when an interior planet has a significant smaller orbital Eccentricity than that of the earth. It turns out that this is indeed the case for Venus, which has the smallest Eccentricity of any planet in the solar system. Thus, Ptolemy was able to successfully account for the apparent motion of Venus. Mercury, on the other hand, has a much larger Eccentricity than the earth. Moreover, it was very difficult for Ptolemy to obtain accurate measurements of Mercury's position in the sky, since this position is always close to that of the sun. Consequently, Ptolemy's Mercury data was highly inaccurate. Not surprisingly, Ptolemy was not able to account for the apparent motion of Mercury using his standard deferent-epicycle approach. Instead, in order to fit the data, he was forced to introduce an additional, and quite spurious, epicycle into his model of Mercury's orbit. This is equivalent to neglecting the interior planets' orbital eccentricities relative to that of the earth

Ptolemy's fourth, and possibly largest, error is associated with his treatment of the moon. It should be noted that the moon's motion around the earth is extremely complicated in nature, and was not fully understood until the early 20th century. Ptolemy constructed an ingenious geometric model of the moon's orbit which was capable of predicting the lunar ecliptic longitude to reasonable accuracy. Unfortunately, this model necessitates a monthly variation in the earth-moon distance by a factor of about two, which implies a similarly large variation in the moon's angular diameter. However, the observed variation in the moon's diameter is much smaller than this. Hence, Ptolemy's model is not even approximately correct.

Ptolemy's fifth error is associated with his treatment of planetary ecliptic latitudes. Given that the deferents and epicycles of the superior planets represent the orbits of the planets themselves around the sun, and the sun's apparent orbit around the earth, respectively, it follows that one should take the slight inclination of planetary orbits to the ecliptic plane (i.e., the plane of the sun's apparent orbit) into account by tilting the deferents of superior planets, whilst keeping their epicycles parallel to the ecliptic. Similarly, given that the epicycles and deferents of interior planets represent the orbits of the planets themselves around the sun, and the sun's apparent orbit around the earth, respectively, one should tilt the epicycles of inferior planets, whilst keeping their deferents parallel to the ecliptic. Finally, since the inclination of planetary orbits is all essentially constant in time, the inclinations of the epicycles and deferents should also be constant. Unfortunately, when Ptolemy constructed his theory of planetary

latitudes he tilted both the deferents and epicycles of all the planets. Even worse, he allowed the inclinations of the epicycles to the ecliptic plane to vary in time. The net result is a theory which is far more complicated than is necessary.
The final failing in Ptolemy's model of the solar system lies in its scale invariance. Using angular position data alone, Ptolemy was able to determine the ratio of the epicycle radius to that of the deferent for each planet, but was not able to determine the relative sizes of the deferents of different planets. In order to break this scale invariance it is necessary to make an additional assumption—e.g., that the earth orbits the sun.

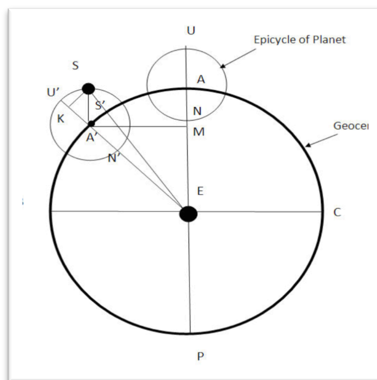
PHILOSOPHICAL DIFFERENCES BETWEEN THE INDIAN APPROACH AND THE GREEK APPROACH

The Greek planetary theories were formulated geometrically and the computational schemes had to be inferred from the geometrical model. On the contrary Indian planetary theories were essentially formulated analytically/computationally and the geometrical picture had to be inferred. In this and in other attributes, the Indic approach is closer to the modern approach than is Ptolemy's Syntaxis. The Indian model can be mapped into a geometric model, whereas the reverse was possible only if they had the skills in algebra, which the ancient Greek did not have

Greek planetary theories were based on the fundamental principle that all the observed planetary phenomena had to be explained based on uniform circular motions. This is an injunction that Ptolemy consistently breaks. Indian planetary theory is free from such constraints. The Islamic Astronomers had a great deal of difficulty reconciling this assumption with the use of a Deferent whose center does not coincide with the earth and that they describe equal angles around yet another center called the Equant.

As regards the actual models of Ptolemy and Āryabhaţa (they should properly be called the Siddhāntic models, there are similarities in the basic parameters such as the rates of mean and synodic motions. Most of these are found in ancient, traditions of Egypt and Babylon. It is difficult to say which civilization has temporal priority, but circumstantial evidence indicates that the Indic formulations on the use of epicycles and eccentrics predates all others, since India was the only country that had a strong tradition in both algebra and geometry as evidenced in the Sūrya Siddhānta and the Sulva Sūtras. The first appearance of the Sūrya Siddhānta has a terminus ante quem of 400 BCE. This comes from internal evidence. Āryabhaţa was the first to come up with an Armillary sphere to visualize the motion of the planets in the Solar system.
We say this because there were other Siddhāntas that were lost over time. This does not mean that there was no work done on the Sūrya Siddhānta after this date. In fact there have been at least 2 redactions since then. More work needs to be done to see what these changes were and when they occurred.

FIGURE 12 INDIAN ASTRONOMY – AN EPICYCLIC APPROACH APPROPRIATE FOR THE EFFECT OF THE MANDOCCA



INDIAN ASTRONOMY - THE SOLAR THEORY (MANDA SAMSKĀRA)

ASSUMPTION = the planet is riding on the epicycle and is rotating counter to the angular velocity of the mean planet, but equal in magnitude.

LEGEND FOR FIGURE 12

A, A' = Madhya Graha, mean planet
E = earth,
ABPC = Kaksyāvrtta,
R = OA = radius of the Madhya Graha orbit
S' = Spaṣṭagraha (Kaksyavṛtta)
AEP is the apse line
UAN is the diameter of the epicycle of the Sun. When the center of the epicycle is at A , the Sun is at U . Let A move with the mean motion of the Sun to A' along the orbit and let the Sun move from U' to S., so that ∡U'A'S = ∡A'EA = Manda Kendra or the Mean Anomaly = λ_m

λ_t = *True Anomaly = ∡**SEA,*** and

λ_t - λ_m =∡***SEA'****= Manda phala or manda correction*

***r =** radius of epicycle*

FIGURE 13 AN ECCENTRIC APPROACH -

Join SE cutting the orbit at S'. Then A' is the Madhyama Sūrya or the mean place of the Sun and S' is the sphuta Sūrya or true Sun

ABPC is the deferent of the Sun with center E, the Kakṣya Mandala, the circle with the centre of the earth as its centre. AEP is the apse line (major axis of ellipse) joining the apogee and the perigee with center A and radius equal to the radius of the place of the Sun's epicycle.

To find the arc A'S', Join SA'. A'M is the Manda Kendrajya or Rsine Mean Anomaly. From similar triangles, SA'K and A'EM,

SK= $\frac{A'M \times SA'}{A'E} = \frac{Rsin\ \lambda_m \times r}{R} = \frac{Rsin\ \lambda_m \times circumference\ of\ epicycle}{2\Pi R}$ = *rsin* λ_m … … … … .. *(29)*

But SK is = ***ρ*** **sin (** $\lambda_t - \lambda_m$**)** ………………………………………………………………………………..*(30)*

where ***ρ*** (Pronounced rho) is the manda karna or hypotenuse of ΔSEK, or the distance from the centre to the Sun , SE, the true radius of the Sun as it makes an apparent orbit around the earth.

Thus ***ρ** Sin (* $\lambda_t - \lambda_m$*) = = r sin* λ_m ………………………………………………………...……………*(31)*

ρ is then **(r sin λ_m)/(sin($\lambda_t - \lambda_m$))**

In this approach the solar planetary system is modeled in 2 stages, manda, and Śīghra.

In stage 1, the true motion of the Sun is calculated, using a Manda correction to the mean Motion. The mean motion of the Sun is expressed by a circular orbit known as the Deferent. The true motion of the planet (Sun, in this case) is expressed by an epicycle a nicoccavrtta, the center of which represents the Mean motion of the Sun. It moves along a deferent circle (kaksyavrtta) with the same uniform rotational velocity as the Sun does in the deferent, except that it is in the reverse direction.

In the second stage, the movement of the planet relative to the Sun is calculated using another epicycle or it can be represented by an eccentric circle (mandaprattivṛtta). In reality, one could mix and match

the 2 approaches (namely the epicyclic and the eccentric), but the most common combination happens to be the use of an eccentric in stage 1 and an epicycle in stage 2.

Thus the correction to be applied to the mean anomaly of the Sun is the angle corresponding to the arc A'S' subtended at E. This value is called the Mandaphala or equation of the center of the Sun and is defined as the true anomaly minus the mean anomaly, i.e. the difference between the actual angular position in the elliptical orbit and the position the orbiting body would have if its angular motion was uniform. It arises from the ellipticity of the orbit, is zero at pericenter and apocenter, and reaches its greatest amount nearly midway between these points. See eqn.28 in Chapter 1.

SĪGROCCA AND MANDOCCA

The relative motion of the Sun and the Earth remains the same regardless whether it is observed from the Sun or the Earth. In either case the motion will be in the form of an ellipse. Similarly the moon also moves in an elliptical orbit, but here we have to remark that the overall motion of the moon may be pretty complex because of the proximity of the Sun, even though the mean motion of the moon may still be an ellipse. The position of the Sun and the Moon the Moon where its velocity is a minimum (at the most distant point in the orbit, the apogee) is called the Mandocca
Orbits of other planets are also ellipses, with small eccentricities, but when viewed from a geocentric viewpoint, it is a vector sum of 2 ellipses, the one a relative motion of the Sun around the earth and the motion of the planet around the Sun. The planet in a smaller orbit (interior planet like Venus is called Śīgrocca), as the average motion is faster in a smaller orbit.

INDIAN ASTRONOMY – ECCENTRIC APPROACH

G the Earth
C the center of the deferent describing the path of the Sun
P the planet rotating around the Sun**.**
A = Apogee, P = Perigee, AP = the apse line, APBC the Sun's circular orbit, GE = ***r*** = radius of the Sun's epicycle,
With G as center draw an eccentric orbit, equal to APBC. This is the **Mandaprattivṛtta** or eccentric or deferent. The apse line cuts it at A' and P', which are the apogee and perigee of the eccentric. Let the mean Sun and the true Sun start at A and A' respectively. Both the mean and the true Sun are assumed to move at the same velocity and in the same direction. The new locations are M and S. Join SE cutting the eccentric at S'. Then M is the mean Sun and S' is the true Sun. So the correction to be applied is the length of the arc MS' which is called the Mandaphala.
arc A's = arc AM= ∠AEM . GS is ll (parallel) EM, also GS= EM. Thus SM is ll GE = radius of epicycle. ∠A'GS =∠AEM = mean anomaly of the Sun = λ_m

$$SH = \frac{KE \times SM}{EM} = \frac{Rsine\ \lambda_m \times r}{R} = \frac{RSin\ \lambda_m \times circumference\ of\ epicycle}{2\Pi R} = r\ sin\ \lambda_m$$

Thus there exists an equivalence between the 2 approaches (eccentric and epicyclic).

There are mainly 3 attributes that Occidentals cite when they claim India borrowed from Greece;
The theory of epicycles – we have shown that beyond the basic use of epicycles, there is very little in common between the 2 approaches
Coincidence in the systems of astrology. I agree that a plausible argument can be made in the case of Astrology for a transmission; however the chronological evidence militates against it.
The ratio of the length of the day versus night during Summer solstice (3/2) – we have dealt with this issue in Chapter III.

CONCLUSIONS ON THE COMPARATIVE STUDY OF GREEK AND HINDU ASTRONOMY

In order to decipher the direction of knowledge transfer, we need a chronology of the various developments in the 2 regions in the fields of Astronomy and Mathematics. While it is true that the Indics and the Greeks both used epicycles, there is much that is different in the manner in which they went about establishing the techniques they used.

Assuming the premise that the basic approach is similar, a statement with which we have a great deal of difficulty, could 2 different civilizations such as Greece and India come up independently with at least a superficially similar approach using epicycles and eccentrics. In order to answer this question, we will analyze this question using a post Keplerian episteme. Let us assume that the orbits of all the planets are ellipses rather than Circles (even Copernicus believed that the orbits were circular). There are 2 properties of an ellipse, which distinguish it from a circle that are relevant to our discussion:

1. **The Eccentricity, or the degree of asymmetry in the ellipse, or the deviation from circularity as measured by the distance of the focus from the geometric centre of the ellipse. That distance GS (see Figure 2 in this chapter) is proportional to e =the Eccentricity and is in fact = ea, where a is the semi major axis of the ellipse. So the asymmetry of the orbit scales linearly with e.**
2. **The other property that distinguishes the ellipse from the circle is the degree of squashines or egginess, when the circle is squashed into an egg shaped figure. It turns out that the squashiness of an ellipse (if we quantify it by the area of the ellipse) scales with the square of the Eccentricity. In fact the area of the ellipse is = $\pi a^2 (1 - e^2)$.**
   Thus for small values of the Eccentricity, this term is indistinguishable from the corresponding value for a circle. Most of the planets have near circular orbits (e <<1), except for Mercury (see table 4)

What does this imply? It indicates that as a first approximation one could neglect the non-circularity of the ellipse while retaining the property of asymmetry. But this is exactly what the Indics and the Greeks did when they used the combination of eccentrics and epicycles. In order to achieve this insight we had to know that the orbits were ellipses. To achieve the same insight without the knowledge that the orbits were ellipses, would have been more difficult, so it is even more incumbent on us to take the time to appreciate the great leap of civilization when they first started applying these principles to modeling the universe. Is this the reason why the Occidental is loath to grant even this minimal recognition to the independence of the work by the Indic? And if we accept his contention that independent effort could not have resulted in what he proclaims to be the high degree of similarity of these 2 approaches, then he is unwilling to entertain even the plausibility of the Greeks plagiarizing from the Indic. There is one other significant issue which is glossed over by the Occident when he transfers his own angst and yearning for a prior antiquity to the Indic and glibly dismisses the higher antiquity of the Indics versus the Greeks and even the Babylonians as antiquity frenzy. He exhibits considerable lack of clarity of

thought when he refuses to acknowledge the consequences of a significant difference in the chronology of an aural transmission versus a scriptural transmission. I am probably being unduly harsh on this issue but for valid reasons. This is an instance of a vastly different weltanschauung between the two world systems. In the Occident, the very word scripture conjures up a higher authority. Unless it is written down it has no validity. In this they forget the origins of their own Abrahamic faith, and insist that the scriptural version, albeit that of a human intermediary is the authoritative version.
Even though he accepts the initial versions of the Veda being aural, he refuses to acknowledge that every item prior to the scriptural era and even later has 2 dates associated with each document, one in which the Veda was originally composed and transmitted aurally and one where it was initially written down in a specific script. This may seem like a trivial and obvious distinction at first blush but it is a distinction that is rarely made when differences arise between the Indic and the Occident about the dates of various events in the Indic past. The Occident always quotes the date when the aural tradition became a scriptural one, whereas the Indic always mean the date when it was first composed orally.

The Indic approach to Astronomy was singularly devoid of any quest for grand cosmological speculations on the nature of the universe. The ancient Indic was primarily interested in the successful computation of the longitudes and latitudes of the Sun, the Moon, and the Planets. The Indian astronomical texts present, with very few exceptions, detailed computational schemes (also known today as Algorithms, which forms the subject of Algorismus) for calculating the positions of the Sun, Moon, and the Planets on any date. Their approach is analytical and Algorithmic and does not dwell on the geometrical visualization of the problem it is this lack of visualization that has made the Indic approach seemingly more difficult to comprehend. In this as in most other endeavors, the ancient Indic was very practical and preferred Ockham's razor to understand the Universe. His approach could be summed up in a parody of Archimedes "Give me a place to stand and I will measure the Universe and locate the objects within it at a given place and time". The apparent lack of geometric visualization was rectified to a certain degree by the work of the Kerala astronomers, especially Parameswara and Nīlakaṇṭa.

It remained for the Islamic astronomers to synthesize both approaches. It is important to note that they received the Indic knowledge in the early decades of the 8th century, and by the time they got to translating the Syntaxis by Ptolemy in the ninth century, nearly a century later[176], they were in a position not only to understand it but to critique it severely, since they were now in possession of mathematical tools {from the Sindhind (Sūrya Siddhānta), Arkand (Khandakhādhyaka), and Arjabhar.(Āryabhaţīya)} that were far in advance of anything that Ptolemy had. It is reasonable to conclude that the interest in Ptolemy and Greek geometry was sparked in part by their prior knowledge of Indian Siddhāntas. Furthermore, the Ptolemaic geometrical representation was more appealing and easier to visualize for the Islamic astronomers and enabled them to comprehend the analytical work done by the Indics. The Indic approach to computational astronomy is best exemplified in the remarks that Bhāskara I makes on the models that were devised to

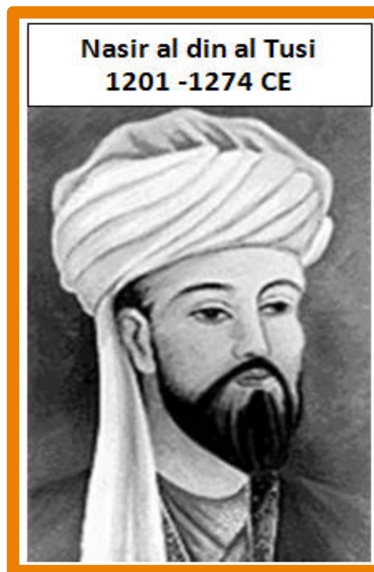


FIGURE 14

[176] *See the timeline of Islamic savants, Table 4 in this Chapter*

compute 'true 'planetary parameters. Bhāskara explains that the study of planetary motion in the Kālakriyāpāda is for the sake of determination of time (kāla-parijñānārthākriyā). Bhāskara also notes:

"*There are indeed no constraints on the notions such as the apsides (uccha, nīcha), mean (madhyama), epicycles (paridhi) etc., as they are only conceptual tools which serve the purpose of arriving at the observed motion of planets and them except that they should lead to observed results. Indeed they are only means to arrive at the desired results*."

There is nothing sacrosanct about a model, at least as far as the Indics were concerned. The main requirement for a model was that it should be representative of reality over a wide range of eras. This is an extremely mature remark, when we consider that the Greeks, violated this principle repeatedly, when they elevated the specific property of circular orbits (uniform angular velocity) to an ontological principle.

The Indic Astronomical tradition involves essentially the following steps:

1. The mean longitude called the madhyama Graha is calculated for the desired day by computing the Ahargana, the number of mean civil days since the nearest epoch when the position of the object was known and multiplying it by the mean daily motion of the planet. 2. Corrections are applied, namely the *manda samskāra* and the *sighra samskāra*, to the mean values of the planet, to obtain the true longitude.

In the case of the exterior planets, Mars, Jupiter, and Saturn the manda samskara is equivalent to taking into account the Eccentricity of the planets orbit around the Sun. Different computational schemes for the manda Samskara are explicated in the vast Indic literature on the topic. The manda correction in all of these schemes coincides, to a first order in Eccentricity, with the equation of the Center calculated in modern astronomy. The manda corrected mean longitude is called the Mandasphuta Graha. For the exterior planets, the Mandasphuta Graha is the same as the true heliocentric longitude.

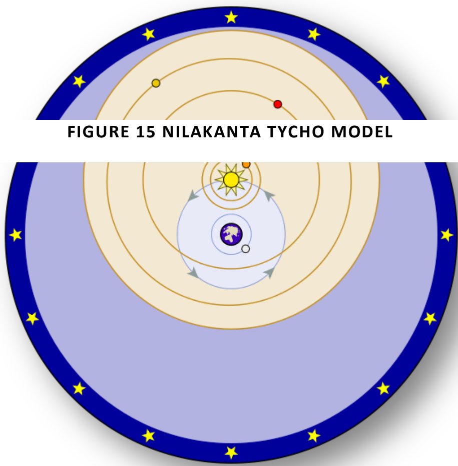


FIGURE 15 NILAKANTA TYCHO MODEL

ISLAMIC ASTRONOMY – THE HOUSE OF WISDOM (BAGHDAD) BAYT AL HIKMA

During the brief period between 750 CE to 1250 CE Islamic Astronomy made a lasting impact on the field. This contribution is extremely well documented and is populated by scientists of the highest caliber. It extends beyond the cataloging of stars and the preparation of Zij's and extends to much original work in both the practical and theoretical aspects of Astronomy.

The initial impetus was provided by the formation of the Bayt al Hikmah in Baghdad, as well as the building of observatories in Samarkand, al Maragha in Persia and in Damascus and Baghdad. Prior to the advent of

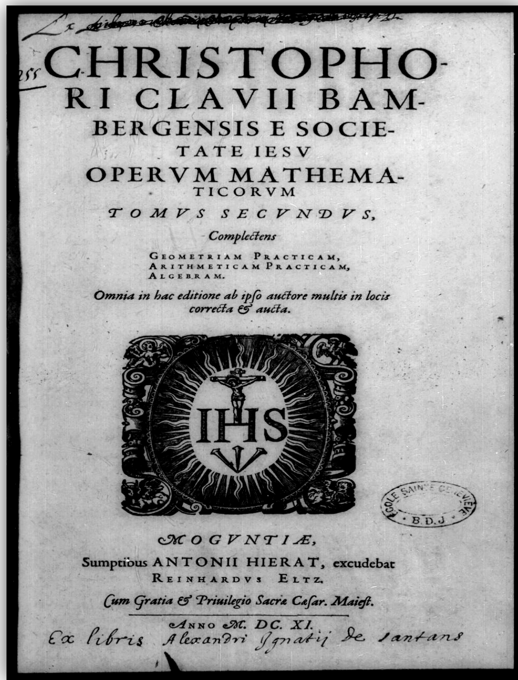


FIGURE 16 CHRISTOPHER CLAVIUS WROTE HIS TEXT ON ARITHMETIC AFTER THE RETURN OF THE JESUITS FROM MALABAR

Mohammad, there was a strong tradition of astronomy at Jundishapur in Persia, encouraged by the Sassanid dynasty. Space restrictions do not permit us to do justice to the Islamic effort and we will confine ourselves to the highlights of this period.

"As the translations of volumes started occupying increasing number of stacks, the Khalīf Al –Ma'amun ordered a library, an observatory and a Museum to be built that became known as the ***House of Wisdom or*** *Bayt Al Hikma. Completed in 833 CE it became the single most outstanding repository of knowledge after the library of Alexandria; a place where scholars pondered the ancient writings and as time went by developed theorems, concepts, and applications of their own. By the second decade of the ninth century, just a generation after Kanaka's arrival, a new and vibrant Arab intelligentsia were making breakthroughs in everything from medicine, chemistry, and optics to a new philosophy of science that framed the pursuit of knowledge in terms of better serving God. In the realm of time reckoning and*

TABLE 6 TIMELINE OF SIGNIFICANT EVENTS IN TRIGONOMETRY, ISLAMIC SAVANTS, AND IMPACT ON TRANSMISSION. THIS LISTING IS OF NECESSITY INCOMPLETE

Date	Description of event
3000 BCE	**YĀJNAVALKYA** see Indic Savants, Chapter XI
2000 BCE	**THE SULVA SŪTRA**, the commonly ascribed etymology of the word Sulva is challenged by Sarasvati Amma[177] who states that the word Sulva (Sulba) does not occur anywhere in the Sulva Sūtras, except in the metrical supplement of the Kātyāyana. Louis Renou lists the following 8 Sūtras, Laugaksi, Mānava, Varāha, Baudhāyana, Vādhūla, Āpastamba, Hiranyakesin, and Kātyāyana as the ones remaining extant. See Indic Savants
600 - 200 BCE	*Jaina astronomy* – first appearance of Sara, later called Utkramjya, see chapter IV
400 – 200 BCE	**SIDDHĀNTA** – first appearance of jya, and a table of values for Sine and Versine, see chapter IV

[177] *Sarasvati Amma, T. A(1)., Geometry in Ancient & Medieval India, Motilal Banarsidass, Delhi, 1979*

400 BCE	**EUCLID** There is absolutely no evidence that a person called Euclid, who compiled the Elements ever existed. For some reasons, the Vatican was interested in maintaining the facade that there was an individual by this name who wrote this book. The dating of Euclid's elements, to a date contemporary with Theon of Alexandria and his daughter Hypatea, changes the entire complexion of the thesis that the Indics borrowed from Greece. By that time, the analytical prowess of the Indic was so versatile, that he no longer had need for the reasoning based on geometry that Ptolemy had to rely upon so heavily in the Syntaxis. Chapter IX. See also the CFM.
200 BCE	**FIRST APPEARANCE OF ZERO IN PINGALA'S CHANDAS SŪTRA,** Gayatri Chandas, and one pada has six letters. When this number is made half, it becomes three (i.e. the pada can be divided into two). Remove one from three and make it half to get one. Remove one from it, thus gets the zero (Śūnya). Pingalacharya In Chanda Sastra 200 BCE. See appendix O.
160 BCE	**HIPPARCHUS**. Credited with development of trigonometry. The Sūrya Siddhānta where the Sine difference table first appears predates Hipparchus by 150 years at least. The Hipparchus Table did not stand the test of time because it was outdated by the time it first appeared. Chapter X.
200 CE	**CLAUDIUS PTOLEMY** We cannot say with any degree of certainty what Ptolemy knew, especially in terms of actual parameters, and whether he was able to compute to a degree of precision higher than that of the Indics. It appears highly unlikely he could do this. The reason – the only evidence of his work is an accreted text that occurs 12 centuries after he lived. His errors do not appear in the Indic approaches to the problem. If his errors had appeared in the Indic approach, then one could have postulated a slight possibility that the Ptolemaic model was lifted in total, errors, and all by the Indics. But that did not happen. Chapter X.
Preferred date? 500 BCE Conventional 477 CE -	**ĀRYABHAṬA** gives a derivation for his formula to compute tables of sines, where he demonstrates that the second difference is equal to the negative of the function A. We will discuss the contribution of *Āryabhaṭa*'s very astute observation and a property of the Sine function in detail in the section on Indic savants. Chapter XI.
Preferred date 96 BCE Conventional 500 CE	**YATIVṚṢABHĀCHĀRYA** Jaina mathematician. Yativṛṣabha (or Jadivasaha) was a Jaina mathematician who studied under *Ārya* Manksu and Nagahastin. We know nothing of Yativṛṣabha's dates except for a reference which he makes to the end of the Gupta dynasty which he says was after 231 years of ruling. This ended in 96 BCE so we must assume that 96 BCE is a date which occurred during Yativṛṣabha's lifetime. This fits with the only other information regarding his dates which are that his work is referenced by Jinabhadra Ksamasramana in 609 and that Yativṛṣabha himself refers to a work written by Sarvanandin in 458. Yativṛṣabha's work *Tiloyapannatti* gives various units for measuring distances and time and also describes the system of infinite time measures. It is a work which describes Jaina cosmology and gives a description of the universe which is of historical importance in understanding Jaina science and mathematics. The Jaina belief was in an infinite world, both infinite in space and in time. This led the Jainas to devise ways of measuring larger and larger distances and longer and longer intervals of time. It led them to consider different measures of infinity, and in this respect the Jaina mathematicians would appear to be the only ones before the time when Cantor developed the theory of infinite cardinals to envisage different magnitudes of infinity. The Practical aspect of this is the facility of working with large numbers, in which the Ancient Indic was nonpareil.
1st century BCE, Pref. date 30 BCE conventional, 499-587CE ***Varāhamihīra***	**REIGN VIKRAMĀDITYA** Writings **VARĀHAMIHĪRA** Pancha Siddhānta. Varāhamihīra develops several relationships between the functions. $\boldsymbol{Sin\,\theta} = \boldsymbol{Cos}\,(\frac{\pi}{2} - \theta)$, $\boldsymbol{Sin^2\,\theta = \frac{1-Cos\,2\theta}{2}}$, $\boldsymbol{Sin^2\,\theta + Cos^2\,\theta = 1}$
Era Vikrama Śaka	named after Vikramāditya 55 BCE
	Writings **KĀLIDĀSA II, AUTHOR OF RAGHUVAMSA , JYOTIRVIDABHARANA**

Preferred date Conventional 600-680 CE	In the 7th century, Bhāskara I produced a formula for calculating the Sine of an acute angle without the use of a table. He also gave the following approximation formula for sin(x), which had a relative error of less than 1.9%: $\boldsymbol{Sin\ x} \sim \frac{16x(\pi - x)}{5\pi^2 - 4x(\pi - x)},\ (0 \leq x \leq \frac{\pi}{2})$
622,July 16	Beginning of Islamic calendar, with **HEGIRA OF MOHAMMAD TO MEDINA**, as the beginning of the era
637 – 650 CE	In a series of battles the Sassanids under **YAZDEGARD III** the Persians were defeated at Quadessiya by the armies of Islam. This was a major coup for Islam, as the intellectual resources and military might of one the largest Asian empires of the world were now at their service. The great Zoroastrian religion, one of the descendants of the ancient Vedics was forever decimated in their own homeland and their remnants, the **PARSEES,** fled to India where they prospered and attained high status in the military, in academia and in Commerce and Industry. Today the Parsees are slowly becoming extinct as a distinct ethnic group and their numbers have dwindled to less than 100,000, but there contributions to humanity remain disproportionately high and far in excess to their numbers .
662 CE	**SEVERUS SEBOKHT** praises the Indics, while accusing the Greek of excessive hubris in claiming to have invented everything *I will omit all discussion of the science of the Indians, ... , of their subtle discoveries in astronomy, discoveries that are more ingenious than those of the Greeks and the Babylonians, and of their valuable methods of calculation which surpass description. I wish only to say that this computation is done by means of nine signs. If those who believe, because they speak Greek, that they have arrived at the limits of science, would read the Indian texts, they would be convinced, even if a little late in the day, that there are others who know something of value."*http://www-groups.dcs.st-and.ac.uk/~history/HistTopics/Arabic_numerals.html See Al Kindi.
680 CE	Ali's second son **HUSSAIN** is defeated at Karbala giving rise to the Shia Sunni split
750 CE- 1000 CE THE ABBASIDS	Defeat of the Umayyad by Khalīf Abul Abbas gives rise to the Abbasids who dominate the Khilafat but the central authority of Baghdad weakened after 1000 CE. The Abbasid court was eclectic and was heavily Persianized.
750 CE	The first contact of the Arabs with the Indic approach to mathematics and astronomy came with the Zij – I- Shahryar, which was an Arabic translation from Pahlavi of an Indian text on Astronomy, translated earlier from Sanskrit to Pahlavi at Jundishapur. Kennedy[178] tabulates the long list of Zij's with characteristic Indian features.
753 -774 CE	**ABBASID KHALĪF AL MANSUR**. His court was visited by an Indian Pandit (a Kanaka) in 773 CE according to Ibn al Adami. Ibn al Adami reports in the year 150 AH there appeared before the Khalīf , a man who had come from India; he was skilled in the calculus of the stars known as the SindHind (I.e. Siddhānta) and possessed methods for solving equations founded on the chords of a circle(i.e. kramjya, Sines) calculated for every half degree. also methods for computing eclipses and other things A Ganaka is one who is computationally proficient in Astronomy' so it is not clear whether Kanaka was his name or his occupation. It could have been both. He was referred to as Kanaka al Hindi. See Chapter 11 on Indian savants.
801 – 878 CE	**ABU YUSUF YAQUB IBN ISHAQ AL-SABBAH AL-KINDI**. Al-Kindi wrote many works on arithmetic which included manuscripts on Indian numbers, the harmony of numbers, (Hisab ul Hindi) lines, and multiplication with numbers, relative quantities, measuring proportion and time, and numerical procedures and cancellation. He also wrote on space and time, both of which he believed were finite, 'proving' his assertion with a paradox of the infinite. Garro gives al-Kindi's 'proof' that the existence of an actual infinite body or magnitude leads to a contradiction in. In his more recent paper, Garro formulates the informal axiomatics of al-Kindi's paradox of the infinite in modern terms and discusses the paradox both from a mathematical and philosophical point of view.
875 – 1100 CE	Several Arabic and Persian author s wrote on the Indian Numeral system and the Algorithmic approach of the Indics including , ***AL DINAWARI*** , tried to introduce Indian numerals into Business ***ABU SAHL IBN TAMIM***, d. 950 Hisab al Ghubar ***ALI IBN AHMAD AL- MUJTABA***,d.987 al Takht al Kabir fi al Hisab al Hindi ***ABU BAKR AL KARKHI,*** d. 1029 Kitāb fi al Hisab al Hindi ***ABU'L HASSAN AL NASAWI,*** Al Muqnifi al Hisab al Hindi (both in Persian and Arabic)1030-1040

[178] *Kennedy, ES, A survey of Islamic astronomical tables, Trans. of the American Philosophical society, NS., 46,(2)(1956), pp.123-177*

<800 CE	*Āryabhaţīya* was translated into Arabic by Abu'l Hassan al-Ahwazi (before 1000 CE) as *Zij al*-Arjabhar.
770 CE	**BRAHMAGUPTA'S KHANDAKHĀDYAKA** was translated as Al Arkand and the Brahma sphuta Siddhānta was translated as "Sind Hind al Kabir" by Mohammad ibn Ibrahim al Fazzari . Chapter XI
	Persian astronomers **ABU ISHAQ AL FAZZARI (D. 160 A.H.)** and his son **MOHAMMAD IBN IBRAHIM AL FAZZARI (D.180 AH)** translated the Brahmasphuta Siddhānta by Brahma Gupta[179]) and called it the Sind Hind. Constructed the first Astrolabe, wrote on the use of the armillary sphere and prepared tables according to the Hijri Calendar. At least six treatises written by Ibrahim Al-Fazzari in Astronomy are still intact.
	On the Brahmasphuta Siddhānta by Brahmagupta Jewish astronomer Yakub ibn Tarik[180] did some translations wrote another Zij called Zij al Nahlil min as Sindhind . Astronomical tables solved with the help of Siddhānta. There is little doubt that the initial tables came from India since the prime meridian was centered on Ujjain[181]. The other reason why this is assumed to have come from India is the first use of the place value system, using decimals. The Europeans would not master this system for another 800 years, but there is no question , that the Islamic savants became quite proficient in the use of this technology and were better able to manipulate the data of Ptolemy, because of the use of Algebra and the decimal place value system, both of which they imbibed exclusively from the Indics.
8th century	Omayyad's constructed an observatory at Damascus just prior to their ouster from power.
786-808 CE	**KHALĪF HAROUN AL RASHID** is aided by the ministerial family (Vizier) named Barmak is from Balkh, and may have been of Indian descent. Was responsible for the first translation of the Syntaxis. Was the AlMajisti a faithful translation of Ptolemy's Syntaxis or a loose recompilation of the accumulated knowledge at the Bayt al Hikmah during the Ninth century.
780 -850 CE	**ABU JA'FAR MUHAMMAD IBN MUSA AL-KHWARIZMI** [182] Book 'aljabr' (explains the etymology of Algebra), number of extant works (3) The great astronomer, mathematician, geographer, historian, and the innovator of the science of 'Algorism'. His book entitled Hisab Al-Jabre wa Al-Muqabalah, Compendium on calculation by Completion and Reduction was translated into Latin by Gerard of Cremona, Robert of Chester, and Adelard of Bath and much later into English by F. Rosen (1831). This book introduced the science of Algebra to the Europeans and was used as the principal textbook for mathematics in their universities until the end of the 16th century CE. Al-Khwarizmi wrote 7 treatises on astronomy which have all been translated into Latin including the zij as Sindhind by Adelard of Bath. Appendix E.
787-886	**J'AFER IBN MUHAMMAD ABU MA'SHAR AL BALKHI,** Persian Astronomer, on the Byzantine calendar. In the 9th century, this Persian astronomer developed a planetary model which can be interpreted as a heliocentric model. This is due to his orbital revolutions of the planets being given as heliocentric revolutions rather than geocentric revolutions, and the only known planetary theory in which this occurs is in the heliocentric theory. His work on planetary theory has not survived, but his astronomical data were later recorded by al-Hashimi and Abū Rayhān al-Bīrūnī. Wrote an astronomic work using Indian methods and parameters. Need to check Indian sources on this.
829 CE	Observatory erected at Baghdad by *Khalīf Al Ma'amun*
800-900 CE	Several redactions of the Syntaxis into Syriac, Pahlavi and Arabic
790- 820 CE	*Yahya ibn Khalid ibn Barmak*, was responsible for getting Ptolemy's Syntaxis translated
810?	*Al-Hassan ibn Quraysh,* translated the Syntaxis

179 Pingree, David The fragments of the work of al Fazzari" JNES, 27,(1968), 97-125

180 Pingree, David "The fragments of the work of Ya 'qub ibn Tariq JNES 29 (1970) 103-23

181 Pannekoek, A, A history of Astronomy, George Allen and Unwin, London and New York, 1961

182 Arabic names - A Muslim child will receive a name (called in Arabic 'ism'), like Muhammad Husain, Thābit etc... After this comes the phrase 'son of so and so' and the child will be known as THĀBIT ibn Qurra (son of Qurra) or Muhammad ibn Husain (son of Husain). The genealogy can be extended for more than one generation. For example Ibrahim ibn Sinān ibn Thābit ibn Qurra, carries it back 3 generations to the great grandfather. Later he may have a child and may gain a paternal name (kunya in Arabic) such as Abū Abdullāh (father of Abdullāh). Next in order is a name indicating the tribe or place of origin (in Arabic nisba), such as al–Harrāni, the man from Harrān. At the end of the name, there might be a tag (laqab in Arabic), or nickname, such as the "goggle eyed" (al-Jahiz) or tentmaker (al-Khayyami), or a title such as the "orthodox" (al–Rashid). Putting all this together, we find that one of the most famous Muslim writer on mechanical devices had the full name Badī al-Zamān Abū al-'Izz Ismail al-Razzāz al-Jazarī. Here the laqab Badī-al-Zamān means Prodigy of the Age, certainly a title that a scientist would aspire to earn, and the nisba al-Jazarī signifies a person coming from al-Jazira, the country between the Tigris and the Euphrates Rivers

800-850 CE	*Al Hajjāj ibn Yusef ibn Matar*, translator of the Elements of Euclid, Ptolemy's Syntaxis. Arabic translations may have been made from Pahlavi. reputedly made the first translation[183,184]
813 – 833 CE	**KHALĪF AL MA'AMUN,** son of Haroun al Rashid, and a son of a Persian concubine had a team of astronomers measure the size of the earth by marking out the distance covered by a degree in longitude. Al Ma'amun leaned towards the Mutazilis, who based their belief on reason rather than on the dogmatic interpretation of the Quran and the Hadith. Eventually the Mutazili were overcome by the Ulema and the strict traditionalist interpretation of the texts prevailed and so ended the Golden era of Islam after 300 years
d 879 CE	Ishaq ibn Hunain, supervised the translation of Greek texts
fl. 850 CE	**CHATURVEDA PRTHUDAKASVAMI (FL. 850),** commentary on the Brahma Sphuta Siddhānta , "Just as grammarians employ ficititious entities, such as Prakrti, pratyaya, Agama, lopa, vikāra, etc to decide on the established real word forms, and just as Vaidyas employ tubers to demonstrate surgery, one has to understand and feel the content that it is in the same way that the astronomers postulate measures of the earth etc., and models of motion of the planets in Manda and Śīghra-pratimandalas for the sake of accurate predictions ". A Model is a representation of reality but not reality itself. In other words he cautions us not to get enamored of one's models. A word of wisdom which is timeless in its relevance.
fl. 850 CE	**MAHĀVĪRA** was a Jaina mathematician who lived in what is current day Karnataka His original contribution was in the area of permutations & combinations. He is credited with the first text solely on Mathematics, divorced from its moorings in Astronomy, the Gaṇita Sāra Sāngraha. Chapter XI
826-901 CE	*ThĀbit ibn Qurra al-Sabi al-harrani* Compiled the Kitāb al Majisti (another Arabic version of the Syntaxis. Wrote more than twenty memoirs on astronomy and geometry, invented the sundial, the balance, and wrote elaborately on the altitude of the Sun and the length of the solar year. His treatise on the balance was translated into Latin by Gerard of Cremona. He was followed in his profession (Astronomy, Geometry, and Mathematics) by his Sons Ibrahim and Sinan, his grandsons Thābit ibn Sinan and Ibrahim ibn Sinan, and great-grandson Abu Al-Faraj. Besides his interest in Astronomy, Geometry, and Mathematics, THĀBIT was a skillful physician, while Ibrahim showed his distinction in geometry. His quadrature of the parabola was the simplest ever made before the introduction of integral calculus. But he was also a supporter of the trepidation theory of precession, which also had currency in India for a very short while. One needs to make critical sturdy of the Al Majisti in order to decipher what was already there in the Syntaxis of Ptolemy.
	According to GJ Toomer "Only the Al Hajjaj version and the Ishaq-Thābit version remains extant in the west"
833 CE	**BAYT AL** *Hikma* The House of Wisdom see chapter IX
850 CE	*Govindaswami (c. 800-850)* obtained more accurate Sine tables using the equivalent of what we would refer to today as Newton Gauss Interpolation formula. Chapter XI
850 CE	**HARIDATTA** (circa 850 CE) wrote Grahachara Nibhandana.
869CE	*Sankaranārāyanan (869 CE)* wrote Sankarnarayaneeyam
870-930 CE	*Ṣridhara (870-930 ce)* who lived in Bengal wrote the books titled *Nav Śatika*, *Tri Śatika,* and *Pātī Gaṇita*. He gave: A good rule for finding the volume of a sphere. The formula for solving quadratic equations. The *Pati Gaṇita* is a work on arithmetic and mensuration. It deals with various operations, including: Elementary operations Extracting square and cube roots. Fractions. Eight rules given for operations involving zero. Methods of summation of different arithmetic and geometric series, which were to become standard references in later works.
882	**VATEṢVARA** (fl 882 - 904 CE), author of Vateṣvara Siddhānta ,follows ĀryaPakṣa and SauraPakṣa
930	**MANJULA (930 CE)** see Chapter X I
958	**PRAṢASTIDHARA (FL. 958**)
865 – 901 CE	**AL RAZI**
Circa 879-890 CE	Tr. of **AlMajisti** by **Ishaq ibn Hunayn** later edited (836-901 CE) by **THĀBIT ibn Qurra al-Sabi**, known as the Ishaq-Thābit Version by Toomer. This is the version that was extant in Europe for at least 300 hundred years, after the fall of Toledo.

183 Suter "Die Mathematiker und Astronomen der Araber und ihre Werke, 1900, p.9)
184 Dreyer, JLE "A History of Astronomy", `953.

880 CE- 928 CE	**ABU'ABD ALLAH MUHAMMAD IBN JABIR AL BATTANI** Derived the value of the tropical year to be 365^d 5^h 46^m $24^{s.}$ which is off (by because of Ptolemy's error. He derived the exact number for Eccentricity of the earth orbit
9th century	The astronomer **MOHAMMAD AL FARGANI** writes an Arabic version of Ptolemy's Syntaxis as a text called the Elements of Astronomy
903-986 CE	**ABD-AL RAHMAN AL SUFI** "On Constellations"
896 -956 CE	**ABU AL HASSAN ALI IBN AL-HUSAYN IBN ALI AL MAS'UDI OF BAGHDAD IN MURUJU-L ZAHAB** (Meadows of Gold) was a Historian who travels to India , Sri Lanka and China & remarks on the Indics "by stating it to be the general opinion that India was the portion of the earth in which order and wisdom prevailed in the distant ages. The Hindus abstained from drinking wine and censure those who imbibe; not because their religion forbids it, but in the dread of its clouding their reason and depriving them of their powers. If it can be proved of their kings that he has drunk (wine), he forfeits the throne for he is not considered to be fit to rule and govern the empire if his mind is affected". This book, completed in 947 and revised in 956, quickly became famous and established the author's reputation as a leading historian. Ibn Khaldūn, the great 14th-century Arab philosopher of history, describes al-Mas'ūdī as an imam ("leader," or "example") for historians. Though an abridgment, *Murūj adh-dhahab* is still a substantial work. In his introduction, al-Mas'ūdī lists more than 80 historical works known to him, but he also stresses the importance of his travels to "learn the peculiarities of various nations and parts of the world." He claims that, in the book, he has dealt with every subject that may be useful or interesting. He writes on India that "a Congress of sages at the command of the creator Brahma invented the nine figures and also the Astronomy and other sciences. The work is in 132 chapters. The second half is a straightforward history of Islām, beginning with the Prophet Muhammad, and then dealing with the caliphs down to al- Mas'udi's own time, one by one. While it often makes interesting reading because of its vivid description and entertaining anecdotes, this part of the book is superficial. It is seldom read now, as much better accounts can be found elsewhere, particularly in the writings of al-Tabarī.
952-953 CE	*Abul Hassan al Uqlīdisī*, wrote Kitāb al Fusul fi Al Hisab al Hindi (952-953 CE). Decimal fractions first appear in The Book of chapters on Hindu arithmetic
939-998 CE , **348-388 AH**	*Mohammmad Abu Al Wafa Al Buzjani,* wrote another version of the AlMajisti, Elements
960-1036 CE	*Abu Nasr Mansur ibn Ali ibn Iraq* proved theorems of plane and spherical trigonometry and derived the laws of Sines and Tangents. Highly accurate tables and techniques for the calculation of trigonometric problems were produced. Abu Nasr's pupil, Al-Biruni (973-1050) applied these techniques with great success to geographic and astronomical problems. Several works published from Hyderabad (AP), India Abu Nasr Mansur was a Persian mathematician. He is well known for his work with the spherical sine law. Abu Nasr Mansur was born in Gilan, Persia, to the ruling family of Khwarezm, the "Banu Iraq". He was thus a prince within the political sphere. He was a student of Abu'l-Wafa and a teacher of and also an important colleague of the mathematician, Al-Biruni. Together, they were responsible for great discoveries in mathematics and dedicated many works to one another. Most of Abu Nasr's work focused on math, but some of his writings were on astronomy. In mathematics, he had many important writings on Trigonometry, which were developed from the writings of Ptolemy. He also preserved the writings of Menelaus of Alexandria and reworked many of the Greeks theorems. He died in the Ghaznavid Empire (modern-day Afghanistan) near the city of Ghazni.
965-1039 CE	*Al Haythem, Abu Ali al Hassan, (Latin Alhazen)* of Damascus nine well known works available in India Al Shuck ala Baţlamyūs (Ptolemy), Solutions of doubts in Ptolemy's Syntaxis , in the first part of the 11th century. Wrote, On the configurations of the world translated by YT Langermann, New York, Garland
fl 961-971 CE	**ABŪ JA'FAR AL KHĀZIN** arranged the postulates of the Elements
966CE	**BHATTA UTPALA OF KASHMIR (FL. 966-969 CE)** wrote commentary on Sūrya Siddhānta. Wrote large number of commentaries on *Varāhamihīra and* others as well as independent treatises. Three of his commentaries have verses at the end indicating the dates on which they were composed. Chapter XI
975 CE	Halayudha (fl. 975)
999 CE	Sripati (son of Nagadeva, 999 CE) see table
D 1007 CE	*Abul-Qāsim al-Maghrīti (d. 1007 CE)* compiled the revision of al Khwarizmi's Zij
973-1051 CE	**AL-BIRUNI, ABU AL-RAIHAN MUHAMMAD IBN AHMAD** Book on his Ta'rikh al-Hind ("Chronicles of India").Chapter XI

D 1009 CE	**ALI IBN ALI SAID ABDERRAHMAN IBN AHMAD IBN YUNIS**, generally referred to as Ibn Yunis says the longitude of the Sun's apogee must be corrected 1° every 70 years. He was able to verify the planetary theories, as he had at his disposal an Observatory. He named his tables the Hake mite tables , by judiciously naming them after his sovereign , Al Hakim
D 1029 CE	***AL KARAJĪ***[185]
970- 1029 CE	*Kushyār ibn Labbān* Four works are extant in India, On distances and Sizes of Planets, On Astronomical Tables, On Astrology, On Astrolabe and its use.
80–1037 CE	Persian savant, ibn Sina aka Avicenna, was later translated by Gerard Cremona.
988 CE	**IBN AL NADIM WARRAQ** of Baghdad wrote the Al Fihrist (Flügel), an Index of all the Books of all the peoples, Arabs, and non-Arabs. This work is a historical and bibliographical work of great significance, as it throws light on all the foreign learning that has influenced the Islamic world .The Fihrist gives a list of Indian works that were translated into Arabic at the instigation of the Barmecides. The Barmecides family acted as Viziers to the Khalīf, and is generally assumed to be of Indic origin. He includes the Hindu numerals, in the list of some 200 alphabets, of India (Hind). these numerals are called Hindisah.
1029–1087 CE	**ABŪ ISHĀQ IBRĀHĪM IBN YAHYĀ AL-NAQQĀSH AL-ZARQĀLĪ (1029–1087),** Latinized as Arzachel. Al-Zarqālī was born to a family of Visigoth converts to Islam in a village near the outskirts of Toledo, then a famous capitol of the Taifa of Toledo, known for its co-existence between Muslims and Christians. He was trained as a metalsmith and due to his skills he was nicknamed Al-Nekkach (in Andalusian Arabic "the engraver of metals"). He was responsible for making a collection of Astrolabe, which exhibit a high degree of craftsmanship. According to the historians of Al-Andalus he was a mechanic and metal-craftsman very crafty with his hands. As an instrument maker he first entered the service of the Qadi Said Al-Andalusi, in the year 1060 he wrote on how to create delicate instruments used in Astronomy, and very soon built instruments for a "prestigious group of scholars", but when they realized his great youthful intellect, they became interested in him. After two years of education in the various Maktabs in the city patronized by Al-Ma'amun of Toledo he eventually became a member of that prestigious group. In the following years he began to invent his own instruments and correct mathematical calculations made by his predecessors and would eventually compile the Tables of Toledo. He is credited with establishing precession of the aphelion. Measuring its rate as 12.04 arc seconds. He was particularly talented in Geometry and Astronomy. He is known to have taught and visited Córdoba on various occasions his extensive experience and knowledge eventually made him the foremost astronomer of his time. Al-Zarqālī was not only just a Theoretical scientist but an inventor as well. His inventions and works put Toledo at the intellectual center of Al-Andalus. In the year 1085 Toledo was sacked by Alfonso VI of Castile Al-Zarqālī like his colleagues such as al Waqqashi (1017–1095) of Toledo had to flee for his life. It is unknown whether the aged Al-Zarqālī fled to Cordoba or died in a Moorish refugee camp.
1048–1126 CE	**GHIYATH AL- DIN ABUL FATEH OMAR IBN IBRAHIM AL KHAYYAMI**, aka Omar Khayyam (D. 519 A.H. 1126 CE who together with Abd Al-Rahman Al-Khazini supervised the Nishapur observatory, collaborated in the reformation of the Persian calendar (which preceded the Gregorian calendar by 600 years and is said to be even more exact), and was one of the greatest mathematicians, astronomers and poets of his time.
1085 CE	*Fall of Toledo* to Catholic Spain. Europe was able to make strides in the various branches of knowledge thanks to the large number of Arab documents that now fell into the hands of the Spaniards at one of the greatest libraries of the middle ages. For example, Ptolemy's Almagest (from the Arabic Al Majisti[186]) was translated into Latin from Arabic reputedly by a Gerard of Cremona in 1175 CE. But how authentic were these translations to the original text after a minimum of 2 translations not to mention the many redactions in Arabic. While the probability that an individual by the name of Batlymus, lived in Alexandra, appears to be better than 50%, the same cannot be said of the authenticity of his writings.
BHĀSKARA II *1114-1185 CE*	*Bhāskara II* is responsible for developing various trigonometric functions (see Indic Savants for more detail) e.g. $\sin(\alpha+\beta) = \sin\alpha \cdot \cos\beta + \sin\beta \cdot \cos\alpha$

[185] *Khalil Jaouiche" India's contribution to Arab Mathematics", Colloque de Saint-Denis de la Réunion, November 3-7, 1997, and published in the book L'Océan Indien au carrefour des mathématiques arabes, chinoises, européennes et indiennes (pp. 211-223), Tournès, Dominique (Ed.), Saint-Denis, Réunion, I.U.F.M.de La Réunion, 1998. Translated by Dileep Karanth.*

186 see endnote 4

1126-1198 CE	*Ibn Rushd Abu Welid of Cordova , known as Averroes*, the center of gravity of Islamic Science shifts to the Iberian peninsula
1175 CE	*GJ Toomer* "the principal channel for the recovery of the AlMajisti in the west was the translation from the Arabic credited to Gerard of Cremona, made at Toledo and completed in 1175 CE". Notice he does not say it is the recovery of the Syntaxis.
1172- 1248 CE	*Ibn Al-Qifti, Djamal al-Din Abu 'l-Hasan 'Ali ibn Yusuf b. Ibrahim ibn 'Abd al-Wahid al-Shaybani*, versatile Arab writer, born in 568/1172 at Qift in Upper Egypt. He received his early education in Cairo and in 583/1187 went to Jerusalem, where his father had been appointed as deputy to the Qadi al-Fadil, the famous chancellor, and adviser of Salah al-Din (Saladin). During the many years which he spent as a student there he was already collecting the material for his later works. He was forced by the disturbances which followed Salah al-Din's death to go in 598/1201 to Aleppo, where, under the protection and with the encouragement of a friend of his father, he was able again to pursue his scholarly interests for several years, until the Atabeg of Aleppo, al-Malik al-Zahir, placed him in charge of the Diwan of the finances, a task which he undertook only reluctantly, but which brought him the honorific title of al-qadi al-Akram. Of the 26 works of Ibn al-Qifti of which the titles are known only two survive: (1) The Kitāb Ikhbar al-'ulama' bi-akhbar al-hukama', usually referred to simply as Ta'rikh al-hukama', which exists in an epitome by al-Zawzani (written in 647/1249), ed. J. Lippert, Leipzig 1903; it contains 414 biographies of physicians, philosophers and astronomers with many statements from Greek writers which have not survived in the original; (2) Inbah al-ruwat 'ala anbah al-nuhat, parts i-iii ed. by Muh. Abu 'l-Fadl Ibrahim, Cairo 1369-74, which contains about a thousand biographies of scholars.
1213 CE	*Sharaf al-Dīn al-Muzaffar ibn Muhammad ibn al-Muzaffar al-ṬŪSĪ,* was a Persian mathematician and astronomer of the islamic golden age (during the middle ages). Tusi taught various mathematical topics including the science of numbers, astronomical tables, and astrology, in Aleppo and Mosul. In numerical analysis, the essence of Viete's method was known to al-Tusi, and it is possible that the algebraic tradition of al-Tusi, as well as his predecessor Omar khayyám and successor Jamshīd al-Kāshī, was known to 16th century Europe an algebraists, of whom François Viete was the most important.
1201 -1274 CE	**MUHAMMAD IBN MUHAMMAD IBN HASAN NASĪRUDDĪN AL ŢŪSI** (born 18 February 1201 in ☐ūs, Khorasan, died 26 June 1274 in al-Kāżimiyyah, Baghdad), better known as Amīr al-Dīn al-Ţūsī; or simply Tūsi in the West), was a Persian polymath and prolific writer: an astronomer, biologist, Chemist, Mathematician, Philosopher, Physician, Physicist, scientist, Theologian and achieved fame by his work on Astronomy during his tenure as Director of the Al Maragha observatory. He was of the Ismaili-, and subsequently Twelver Shī'ah Islamic belief. The Arabian scholar Ibn Khaldun (1332-1406) considered Tūsi to be the greatest of the later Persian scholars. Nasir al Din al Tūsi wrote a book with 20 chapters on the Astrolab, and is credited with determining the rate of Precession that was the most accurate for many centuries, till the modern era.
1258 CE	***HULAGU IL KHAN, THE GRANDSON OF CHENGHIZ RAZES*** Baghdad to the ground but astronomical work continues at Maragha in Iran under the supervision of Al Tūsi.
d 1266CE	**MU'AYYAD AL-DIN AL-'URDI (DIED 1266)** was an Arab Muslim Astronomer architect mathematician and engineer working at the Maragheh observatory. He was born in Aleppo and later moved to Maragheh, Azarbaijan, Persia, to work at the Maragha observatory under the guidance of Nasir al-Din Tūsi. He is known for being the first of the Maragha astronomers to develop a non-Ptolemaic model of planetary motion In particular the *Urdi lemma* he developed was later used in the geocentric model of Ibn al-Shatir in the 14th century and in the heliocentric Copernican model of Nicolaus Copernicus in the 16th century. As an architect and engineer, he was responsible for constructing the water supply installations of Damascus, Syria.
d 1283 CE	**MUHYI AL DIN AL MAGHRIBI,** made observations at al Maragha observatory
d 1311 CE	**Qutb al Din al Shirazi, (1236 – 1311)** 13th century Persian Muslim polymath and Persian poet who made contributions to astronomy, mathematics, medicine, physics, music theory, philosophy and Sufism. Spent a short time at al Maragha. Claimed that the delay in the leap year occurred twice in a 70 year cycle in the 29th and 70th year. This would result in an average calendar year of 365.24285^{d} or 54.43^{s} too long.
1259-1316 CE	**MARAGHA OBSERVATORY** built under the patronage of Hulagu Khan, who converted to Islam after having razed Baghdad and Damascus to the ground; the purpose was to update astronomical parameters. Nasir al Din al Tūsi was the director of the Observatory. Compiled the Zij I Ilkhani (named after the Ilkhan).
1304 CE 1375 CE	**ALA AL-DIN ABU'L-HASAN ALI IBN IBRAHIM IBN AL-SHATIR** (1304 – 1375) developed the concentric

	planetary scheme of nested spheres that were free from the equants and eccentrics of Ptolemy, but according to Gingerich (1992) his work was not well known in medieval Europe. This is an example of the double standard used by the Occident,[187] when deciding whether there was a transmission or not. It strains credibility to ask us to believe that Copernicus did not know of the work of al-Shatir, as claimed by Owen Gingerich. By taking such unreasonable stances, the Occidrent has lost its prestigious right to claim that everything they say has to be accepted.
743 AH,1342CE	**LEONARDO OF PISA** wrote Liber Abaci, no manuscript of that name however is extant, but an Arabic version is available in the Bodleian Library as manuscript marked CMXVIII Hunt 214. One of the first treatises to expound on the decimal place value system. This is the beginning of the European rise to dominance in the sciences.
	Translations into Sanskrit from Persian/Arabic and original works
fl1351-1388 CE	**MAHENDRA SŪRI** 1349 CE - The first treatise on the Astrolabe called Yantraraja in the Indian subcontinent. He was the court astronomer for Mohammad Shah Tughlak. A Zij was prepared under Tughlak Rule.
1340–1425 CE	**MĀDHAVA** derived several infinite series for trigonometric functions, including sin, cos and the arc-tangent. This permitted evaluation of transcendental functions up to as many decimal places as one wished. Calculated π to 32 places. Chapter XI.
1380-1430 CE	*Ghiyath al-Din Jamshid Mas'ud al-Kashi*, circa 1380 in Kashan, Iran Died: 22 June 1429 in Samarkand. Astronomer for Ulugh Beg. It was to Ulugh Beg that Al-Kashi dedicated his important book of astronomical tables *Khaqani Zij* which was based on the tables of Nasir al-Tūsi. In the introduction al-Kashi says that without the support of Ulugh Beg he could not have been able to complete it. In this work there are trigonometric tables giving values of the sine function to four sexagesimal digits for each degree of argument with differences to be added for each minute. There are also tables which give transformations between different coordinate systems on the celestial sphere, in particular allowing ecliptic coordinates to be transformed into equatorial coordinates. See188 for a detailed discussion of this work.
d 1449 CE	*Ulugh Beg*. Turco-Mongol grandson of Timurlang. Ulugh Beg was also notable for his work in astronomy-related mathematics, such as trigonometry and spherical geometry. He built the great observatory in Samarkand between 1424 and 1429. He was killed by his son.
d.1622 CE	*Al Amili Tashrih Al Aflak*, Description of the spheres.
1423–1461 CE	**PEUERBACH** authored with **REGIOMONTANUS** (1436- 1476) the first printed version of the epitome of the Syntaxis. **GJ TOOMER** "Manuscripts of the Greek text began to reach Europe by the 15th century, but it was Gerard's text translated from the Arabic, which underlay books on astronomy as late as the Peuerbach- Regiomontanus Epitome of the Almagest. It was also the version that was printed in Venice in 1515. So the current version of the Almagest is at least as modern as the 15th century and is not of 2nd century vintage, as is usually implied by the Occident, especially when granting precedence to Greece vis a vis India, in matters pertaining to Trigonometry, Geometry and Astronomy".
D 1437 CE	Qadi Kadeh al Rumi
1444-1544 CE	**NĪLAKAṆṬA SOMAYĀJĪ (*1444–1544*)**. Of Kelallur, son of Jatavedas, Bhatta, following the Aśvalāyana Sūtra of the RV wrote Āryabhatīyabhāsya, 1977 (Available in Library of Congress) Trivandrum series. Pupil of Parameșvara's son, Damodara, advocate of DrgGaṇita system. Proposed a partial Heliocentric system (we will refer to this systems the Nīlakaṉṯa-Tycho system), where he asserted that the inferior planets (Venus and Mercury) revolved around the Sun. His commentary on Āryabhaṯa's derivation of the sine Difference table is a masterpiece. Chapter IX,XI.
1450 CE	A nautical almanac is prepared to help Portuguese and Spanish navigators. A German Cardinal , **NICHOLAS OF CUSA** speculates that the earth revolves around the Sun.
1473 CE – 1543 CE	Birth of **NICHOLAS COPERNICUS**. By 1510 he proposed the heliocentric universe with the earth revolving around the Sun. Around 1530 he completed De Revolutionibus Orbium Caelestium which expounded the same concept. Copernicus retained the Ptolemaic framework of deferents, epicycles, and circular motions. He was preceded by Al Shatir who developed a similar heliocentric model without the use of equants. The west has completely stonewalled the work of Al-Shatir.

187 See Prologue, section on 'Differing standards of Claims for Transmission of Knowledge'
188 J Hamadanizadeh, The trigonometric tables of al-Kashi in his 'Zij-i Khaqani', Historia Math. 7 (1) (1980), 38-45

1500 -1601 CE	**JYEṢŢHADEVA** (wrote in Malayalam, circa 1500 - 1610) was an astronomer-mathematician of the Kerala school of astronomy and mathematics founded by Saṇgamagrāma Mādhava (c.1350 – c.1425). He is best known as the author of *Yuktibhāṣa*, a commentary in Malayalam of Tantrasamgraha by Nīlakaṇṭa Somayājī (1444–1544). In Yuktibhāṣā, Jyeṣṭhadeva had given complete proofs and rationale of the statements in Tantrasamgraha. This was unusual for traditional Indian mathematicians of the time. An analysis of the mathematics content of Yuktibhāṣā has prompted some scholars to call it "the first textbook of calculus". Jyeṣṭhadeva also authored *Drk-karana* a treatise on astronomical observations. It is the first systematic treatment of problems in Mathematics and Astronomy to appear anywhere in the world.
1500 CE	**MERCATOR** - Chart giving luxodromes as straight lines 1. Worked with Gemma Frisius. At Catholic University of Louvain. 2. Obtained projection from China, table of secants from India. 3. Sources of secant values not known to this day; was arrested by the Inquisition. Had reason to hide "pagan" sources. 4. Chart required more precise secant values than were then available in Europe.
1550-1650 CE	*Sankara Variyer,* pupil of Jyeṣṭhadeva
1552 CE	**BHASKARA'S WORK LILĀVATI IS COPIED WITHOUT ATTRIBUTION BY A JACQUES PELETIER** That Bhaskara's works were well known in Europe is demonstrated by Table 5[189] where the author (Albrecht Heeffer) compares the contents of a randomly chosen arithmetic or algebra book by a Jacques Peletier. The virtual identity of the table of contents of the Līlāvati, written roughly in 1150 CE with the contents of a randomly chosen French text, authored by Jacques Peletier[190] of the 16th (1552 CE) century, indicates a direct connection between the two. It appears more than likely that Peletier had a French translation of Līlāvati available. (See chapter XI) but without the identification of the author and the original language in which it was written. This is another example of the assertion that Europe was very aware of the Indic work.
1559-1632	*Nārāyaṇa Bhattathiri* (1559–1632). There is a lot of circumstantial evidence that the Jesuits learned the trade of Indic Jyotiṣa from either Nārāyaṇa or his brother Sankara Variyer, the Jesuits having convinced the King of Travancore, of their desire to learn the same.
1582 CE	**CHRISTOPH CLAVIUS** Director of Gregorian Calendar Reform Committee, March 25, 1538 – February 12, 1612. 1. The Pope stated length of year was obtained from Alphonsine tables-but these were known from centuries earlier from Toledo.
1610 CE	2. Tried to determine the length of the year observationally, but failed. 3. Deputed a delegation of specially trained Jesuits (among whom were Ricci and Giovanni Rubino[191] to go to India and learn navigation techniques, Trigonometry and calendrical astronomy.

[189] Albrecht Heeffer' 'The tacit appropriation of Hindu Algebra in Renaissance Practical arithmetic'. This is Chapter IV of his PhD thesis. Also appears in Gaṇita Bhāraţi, vol. 29, 1-2, 2007, pp. 1-60.

[190] Peletier, Jacques - L'arithmetique. Parigi, Marnef, 1552

[191] Giovanni Antonio Rubino (1578-1643) was a student of Christoph Clavius (1537-1612) and he was sent to India just like Matteo Ricci (1552-1610) to China. Of course, both worked in Cochin. As Clavius was establishing the Collegio Romano as a centre of mathematical and astronomical skill and authority, he was intent on getting all mathematical and astronomical books from India. As a faithful student, Rubino wrote from Chandrapur, the seat of the Rajah of Vijayanagar, to Clavius in 1609 as follows:

"I am in the great Kingdom of Bisnagà (Vijayanagar), attempting to procure the conversion of these souls, but for the moment clausa est ianua, we are waiting for the Lord to open it, so that many souls will be saved from going miserably to hell. The Brahmańas, who are the literati of this kingdom, are very given to the cognition of the movements and conjunctions of the planets and stars, and in particular of 27 of them by which they govern and rule themselves. Your Reverence will be amazed at how they predict the hour and minute of eclipses of the sun and the moon, without knowing the way in which eclipses occur. I have attempted many times to make them state the way in which they derive the conjunctions of the planets, but I was never able to get them to declare it, and they don't wish to teach the things they know to others, except in secret to their relatives". In the Indic tradition, there is a notion that the student must be qualified in order to benefit from the teaching, just as a PhD candidate is asked to qualify himself before he undertakes to teach him. It would not be at all surprising to us, if we found that indeed, they had in reality told the Jesuits, that it was not customary to teach these subjects to those who were not qualified.

	4. Protestants did not accept the new calendar. Since length of the year could not be accurately determined then by Europeans. 5. Accurate trigonometric tables with a). Sudden increase of accuracy to 8 decimal places. b). Method not explained. c). Same process took a thousand years in India. d). Was well aware of practical importance of these values but did *not* know how to use them to fix the size of the globe. 6. As top Jesuit had full access to translations coming in from India. 7. Wrote his text the Opera Mathematica in 1611. That would have given him enough time to absorb the new knowledge from India, so that he could then explain the same in a pedagogical text. He died shortly thereafter.
1561-1613 CE	*Barthelemy Pitiscus* (August 24, 1561 – July 2, 1613) for its first book on Trigonometry. *Trigonometria: sive de solutione triangulorum tractatus brevis et perspicuus* (1595, first edition printed in Heidelberg). 17 centuries after Hipparchus. The timing of this book, immediately after the intelligence gathering visit of the Jesuits to Malabar, is suggestive that they may have gotten a lot of new knowledge including Trigonometry
1585 CE	Simon Stevin - Decimal system, Proposed a revolutionary change from the existing Roman system of numeration. Probably the single most important factor in the subsequent rise of the sciences in Europe. So after 1700 years, the Occident finally admitted the superiority of the DPV system. This was the beginning of rapid progress in Europe.
circa 1610 CE	*Roberto de Nobili* , Polemic against Vedāńga Jyotiṣa (of ca. -1350 BCE rejected by Indian astronomers as obsolete since at least the 6th CE and superseded by Siddhāntic astronomy. Learnt Sanskrit and also the Veda falsely claiming to be a Brahmin (truth-seeker)! This was a pre-planned strategy of getting influential higher-caste converts to Christianity. Shows how tenaciously Jesuits sought Indian sources like the Vedas & the Vedāńga texts, while publicly berating the Indic philosophy and episteme.
circa 1585	**TYCHO BRAHE** Tychonic system. Did he have prior knowledge of Nilakanta's work? 1. Introduced naturally by Nīlakaṇṭa a century earlier. 2. Tycho had the system first, and looked for observations later. 3. His fame as an astronomer, and position in church hierarchy made him the natural person to whom new astronomical books from India would have been referred.
circa 1615	**JOHANNES KEPLER** Kepler's laws and super-accurate orbit of Mars. I. Obtained access to Tycho's papers on his death but fudged his observations. Since his theory (very similar to Nīlakaṇṭa's) was more accurate than Tycho's observations which he claimed to have used. 2. Was a professional astrologer, used to telling stories? 3. Experimented with the calculus in *Stereometria Doliorum* (1615 CE).
1652 CE	**CAVALIERIi** 1652 Method of indivisibles. 1. Discovery comes after first use of decimal notation. 2. Uses Indian technique but tries to provide geometric explanation for them.
1635 CE	**PIERRE FERMAT** did not publish challenge problem to British mathematicians. It was a solved exercise in Bhāskara II. A lot of the ideas of the calculus, now attributed to Fermat was clearly lifted from Lilavati, which was available to Fermat and Pascal. (See chapter 11).
1635 CE	***PASCAL,*** Quadrature of higher order parabola Pascal's triangle known to Indian tradition as Pingala's Meru Prastara of high antiquity, terminus ante quem is 200 BCE. also known to Chinese Uses the leading order expressions for $(1/n^{k+1})\Sigma_{i=1}^{n} i^k$
1582 CE	**JOSEPH JUSTUS, SCALIGER**, Julian Day Count I. Similar to Indian *ahargana* system, with adjusted zero point. 2. No earlier background of astronomical calculations using this system in Europe.

The Jesuits would not be likely to volunteer the information that they were not regarded as being qualified.

circa 1627 CE	**GALILEO** refused to write on the Calculus presumably because he couldn't understand it 1. Had full access to the Jesuit Collegio Romano. 2. Cavalieri waited 5 years for him to write. 3. Criticized Cavalieri's approach to infinities suggesting various paradoxes.
1687 CE	**JEAN DOMINIQUE CASSINI** and the Siamese manuscript - Coming back to Cassini, we need to record his role in the discovery of Ancient Indian Astronomy. It was the French Ambassador to Siam (Thailand), M. de la Loubére who brought to Paris, in 1687 a manuscript containing rules for the computation of the longitude of the Sun and the Moon. The interpretation of the manuscript proved to be a difficult task but Cassini was probably impressed sufficiently with the manuscript, that he undertook the difficult task. Cassini communicated the results of his investigations, which were reprinted in Mémoires de l'Academie royale des sciences (1699). If Cassini knew of the Siddhāntic manuscript, it hardly makes sense for the European to argue that the work done in India was not familiar to Europe. It is quite clear that they had extensive knowledge of the Indic contributions from multiple sources
1760 CE	*Leonhard Euler, ca 1760 CE* ; Euler solver, Pells equation 1. Wrote an article on the Indian sidereal year, indicating he had access to Indic contributions. See for example[192]. 2. Published first European solution to Fermat's challenge problem from Bhāskara and called it Pells equation; must have had access to Fermat's Indian sources. 3. His ODE solver is similar to Indian interpolation technique. 4. Received prize for work on Longitude. 5. His continued fraction expansion for π similar to Indian continued fraction expansion.
June 2, 1916 – May 3, 1988 CE	The Late *Abraham Seidenberg* of UC, Berkeley in his land mark papers on the origins of Geometry and Mathematics is to be commended for sticking to his convictons that the origins of Geometry lay in a system that should be very similar to the geometry in the Sulva Sūtras (SS). This despite strenuous opposition from the Indologists, who generally are strangely silent about the chronology of the SS, and if they do mention the SS, they maintain it has Terminus post quem of 800 BCE. This is much too late a date to assign to Āpastamba, Baudhayāna and Mānava
Feb 2, 1903 to January 12, 1996	*Bartel Leendert van der Waerden* (February2, 1903, Amsterdam, Netherlands – January 12, 1996, Zürich, Switzerland) was a Dutch mathematician and historian of mathematics. Āryabhaţa in his magnum opus *Āryabhaţīya,* propounded a computational system based on a planetary model in which the Earth was taken to be spinning on its axis and the periods of the planets were given with respect to the Sun. B. L. van der Waerden has interpreted this to be a heliocentric model but this view has been strongly disputed by others.[193]
May 26, 1899 – February 19, 1990	*Otto Neugebauer* was schizophrenic when it came to the antiquity of the Indic contributions. While he admitted that that much more work needs to be done to decipher the Indic contribution, he was unwilling to concede that the Indic contributions predated most the developments that took place in Greece and Babylon.
January 2, 1933 New Haven, Connecticut - November 11, 2005	**DAVID PINGREE**, had only 1 mantra, which he repeated in every paper, namely that India borrowed everything from Greece.

Astronomy, they applied Greek and Indian ideas about measuring time to a practical need for their religion: when exactly they should kneel and pray, which Mohammed required all Moslems to do five times a day.

This inspired early Arab astronomers to use and improve upon Greek instruments such as the astrolabe,

192 Euler, Leonhard., "On the Solar Astronomical Year of the Indians", tr. by Kim Plofker, http://www.math.dartmouth.edu/~euler/Estudies/Plofker.pdf

193 B. L. van der Waerden (1987), "The heliocentric system in Greek, Persian, and Indian astronomy", in "From deferent to equant: a volume of studies in the history of science in the ancient and medieval near east in honor of E. S. Kennedy", New York Academy of Sciences 500, p. 525–546.

sundial, and globe to better calculate the angles of the sun at various times of the day. "Astronomers also advised architects throughout the Moslem world where to build mosques so that the faithful could follow another command of the Prophet-that they always face the direction of Mecca when they pray, whether they are in the Hindu Kush or on the Rock of Gibraltar."[194]

If we examine the timeline of events in the Islamic universe given in Table 6, it is clear that the Entrepôt that the house of wisdom had become, resulted in advancements in the state of the art of Astronomy, where Ptolemy's model was increasingly questioned and is also clear that the precision with which calculation were being carried out was far superior to the Syntaxes of Ptolemy written presumably in the 2nd century.

Generally Occidental writers and JL Dreyer[195] in particular, have been unduly harsh on the Arab contribution. They fail to mention the advances made by the Al Maragha School and the part they played in the transition to heliocentric paradigm. But in fairness he has been an equal opportunity denigrator of any tradition that did not have a connection to Europe and in fact his criticism of the Indic is even more scathing.

By so doing, the historian from the occident kills in effect two birds with one stone. He absolves himself from giving an extensive treatment of these topics and he sidesteps the more important question of his competence in dealing with the subject, saddled as he is with ignorance of Sanskrit and the inability to examine primary sources without having to rely on others for making crucial judgments. I have only read of 2 investigators (Otto Neugebauer and Emmeline Plunkett) who had the courage to admit that they could not make final judgments on the Indic contribution because of their inadequacy in reading the vast literature on the subject in Sanskrit.

Most exhibit the hubris that comes with being on the same side as the colonial power that they know better than the Indic about his own history and will remind one at the very outset that failure to agree with them will result in loss of membership in the exclusive club known as "mainstream historians".

In this, as in other issues relating to the place of India in the world, there is a certain degree of culpability on the part of the Indic as he is unable to wean himself away from dependency on the Occidental for his needs of approval and self-esteem, by shirking the difficult decisions that come with nation building and national identity. He has let the Occidental define the terms of debate and has even let the Occidental define who he is.

PTOLEMY

"In general we will use the sexagesimal system, because of the difficulty with fractions, and we shall follow out the multiplications and divisions" , translated by R Catesby Taliaferro, Great Books of the Western World, vol.15, Encyclopedia Britannica, Chicago , 1996., P.14

[194] David Duncan Ewing "Calendar; Humanity's epic struggle to determine a true and accurate Year" Avon Books, New York, 1998

179 Dreyer, JL "A history of astronomy from Thales to Kepler" second edition, 1953, Dover, NY.

CHAPTER IX
THE TRANSMISSION OF KNOWLEDGE

The story of how the Vatican in particular and almost the entire intellectual elite in Europe collaborated over several centuries to deny the civilizations in the rest of the world their contributions to the epistemic progress in knowledge, is indeed a sordid one . This pattern of behavior is peculiar to the Catholic Church and has been practiced assiduously over several centuries. It has been institutionalized under the Law of Christian discovery. Eventually the law of Christian Discovery was adopted by the USA in 1823, in order to give legality to the seizure of the real estate in the Americas from the natives. It is this institutionalization of intellectual property (not to mention Real Estate) theft from those who were deemed pagan and therefore less than human, that has made the Occidental even to this date immune to feelings of remorse. The practice of taking over significant discoveries and concepts from other traditions continues on till this day, since the underlying rationale is that, if the people they were stealing from were pagan, and then such a behavior was sanctioned by the highest authority and therefore was not wrong. We will mention several such instances, and will elaborate on a couple to establish the modus operandi of such theft.

Under various theological and legal doctrines formulated during and after the Crusades, non-Christians were considered enemies of the Catholic faith and, as such, less than human. Accordingly, in the bull of 1452, Pope Nicholas directed King Alfonso to "*capture, vanquish, and subdue the Saracens, pagans, and other enemies of Christ," to "put them into perpetual slavery," and "to take all their possessions and property.*"[196] Acting on this papal privilege, Portugal continued to traffic in African slaves, and expanded its royal dominions by making "discoveries" along the western coast of Africa, claiming those lands as Portuguese territory. When Columbus sailed west across the Sea of Darkness in 1492 - with the express understanding that he was authorized to "take possession" of any lands he "discovered" that were "not under the dominion of any Christian rulers" - he and the Spanish sovereigns of Aragon and Castile were following an already well-established tradition of "discovery" and conquest. Indeed, after Columbus returned to Europe, Pope Alexander VI issued a papal document, the bull *Inter Cetera* of May 3, 1493, "granting" to Spain - at the request of Ferdinand and Isabella - the right to conquer the lands which Columbus had already found, as well as any lands which Spain might "discover" in the future.

It is clear that in both cases, theft of real estate and theft of intellectual property there was great encouragement from the major theological institution of the time, with the result that those of us not residing in the countries benefiting from such generosity might be left wondering, as to the role of the church in the occident. We refuse to be sidetracked, however, from our prime purpose in chronicling these events, while we remain highly skeptical of pronouncements of the Church when it comes to historical matters. Eusebius[197], a chronicler of early church history was frank in admitting that his job as historian was to be hopelessly biased towards Constantine presumably because Constantine was his employer and put food on his table. This merely indicates that Eusebius was part of a tradition in the Church which was unabashedly wedded to an account of history where adherence to the truth was

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[196] *Davenport, Frances Gardiner, 1917, European Treaties bearing on the History of the United States and its Dependencies to 1648, Vol. 1, Washington, D.C.: Carnegie Institution of Washington.*

[197] *Eusebius of Caesarea (c. 263 – c. 339[1]) (often called Eusebius Pamphili, "Eusebius [the friend] of Pamphilus") became the bishop of Caesarea Palaestina, the capital of Iudaea province, c 314.[1] He is often referred to as the Father of Church History because of his work in recording the history of the early Christian church, especially Chronicle and Ecclesiastical History,*

incidental and certainly not the main criterion. Faced with such an amoral stance by their own church many in the occident have made the assumption that if their own church was so utterly lacking in ethics, that other traditions must be similarly afflicted and despite the fact that there is no evidence of an entrenched religious hierarchy in the entire history of India and that the power of the priesthood in India was nowhere near as extensive as in the occident, continue to make the convenient assumption that that the source of all evil in India is the Brāhmaṇa. Such an assumption has the added advantage of killing more than one bird with one stone, by eliminating the main source of intellectual leadership, so that the task of supplanting and replacing native traditions is facilitated
Nevertheless, a European scholar refutes the skepticism surrounding the study of history. She argues that history is knowable via a critical analysis of the following:

Written evidence.
Eye witness testimony.
Photographs/cartoons/paintings/etching.
Archaeological remains.
Inferential evidence.

This sounds suspiciously like one of the many pramānās that we describe in Appendix D and this is what we feel needs to be done.

We need to make one more point in relation to the transmission of knowledge from India to other parts of the world. In every instance, whether it was China, South East Asia, it was freely sought after by the recipient civilization and there was no compulsion in the adoption of the resulting technology whether it was the script or Mathematics or astronomy. There was no attempt to hide the source of the technology. In fact they spoke of the technology in glowing terms and their pride in successfully grafting to their own civilization. If the Indics had adopted their technology from the Occident, they would have similarly been quite proud to state that they had successfully grafted it to their own. There would be little reason for them to hide the source, as the Occidental maintains.
Before we discuss the well documented links in the chain of knowledge transmission, we will recall that there are no Greek savants in science (and especially mathematics) who hail from what we think of as Hellenic Greece. Almost all of the scientists of the ancient Greek era hail from what is now Turkey (Asia Minor) and what was known as Ionia (and that includes Thales, Aristarchus, Hipparchus, Pythagoras, Archimedes) and the later Greeks after the establishment of Alexandria , were Alexandrian. So almost the entire lot would be classified properly as Asian or African. The only reason I bring this up, is the inordinate importance that Occidental historians give to the Hellenic origin of trigonometry.

In the following sections, we have chosen several instances to illustrate the manner in which the Occident developed a collective amnesia regarding the contributions of the Indics. These examples do not exhaust all of the historical narrative which provides a veritable embarrass de riche, supporting our thesis that the Knowledge transfer was from East to West. However they constitute a damning cornucopia of counter examples, so conclusive that any attempt to revive an alternate hypothesis would invite scorn

- David Pingree as the quintessential example of the process
- Greece and India in the Ancient Era
- The case of the Elusive Euclid
- The Indic University Tradition
- The Academy at Jundishapur
- The founding of the Library of Alexandria
- The Case of Ptolemy

- The Case of the Missing table of Sine differences
- Did Hipparchus invent Trigonometry
- Āryabhaţa's π & the ingenious Sine table
- The Case of Jean Dominique Cassini (the Astronomer for Louis XIV)
- The Case of the determination of Longitude at sea - Time equals longitude
- The Case of the Redundant Equant
- The nature and extent of Proof in Ancient Indian Mathematics
- Nilakanta's unified treatment of planetary motions
- The case of the plagiarism of Bháskaráchârya's Lilavati in 1552 (see chapter XI)

DAVID PINGREE'S VERSION OF THE HEGELIAN HYPOTHESIS

David Ewins Pingree was an extraordinary individual. He graduated from Harvard in 1954 and went on to work with Otto Neugebauer, arguably the most well-known Historian of Mathematics of the twentieth century and eventually played a long innings as a Professor of the History of mathematics at Brown University, Providence, RI. He compiled a Census of the Exact Sciences in Sanskrit (CESS). He completed his PhD thesis on "Materials for the Study of the Transmission of Greek Astronomy to India". We will let him describe his life and the passion that he had for the History of the sciences in his own words
"Throughout my scholarly career I have enjoyed the great advantage of close association and collaboration with a number of excellent scholars—Classicists, Medievalists, Byzantinists, Arabists, Assyriologist, Egyptologists, Iranologists, and Sanskrit scholars, as well as Historians of Science. Among all of these the most influential on my career was Otto Neugebauer,[198] who showed me how to interpret correctly ancient astronomical texts and tables in various ancient languages and to demonstrate the dependence of one culture's mathematical models and parameters on another's.

My interest in the transmission of scientific ideas from one culture to another was awakened in 1955, the year after my graduation from Harvard College where I had concentrated on Classics and Sanskrit. I spent that year in Rome on a Fulbright, studying the paleography of Greek manuscripts in the Vatican Library. In the margins of one such manuscript, Vaticanus graces 1056; I noticed references to Indian astrological ideas. In the library I found a printed edition of Varāhamihīra's Brihatjātaka[199] and found therein Nagari[200] transliterations of Greek technical terms. Since the material in Vaticanus Graecus 1056 was clearly translated from Arabic, it was clear that Greek astrology had travelled to India, from there to Islam, and thence to Byzantium.

As I soon found out, very little research had yet been carried out in this field. In order to familiarize myself with the ancient and Byzantine Greek traditions in astrology I spent 1956–57 and 59–60 at Dumbarton Oaks as a Junior Fellow and in 1958–59 I went to India to study Sanskrit astrological manuscripts primarily at the Bhandarkar Oriental Research Institute in Poona. At the latter institute I happily met the great authority on Dharmasastra,[201] P. V. Kane who very kindly gave me the several folia

[198] See Noel M. Swerdlow, "Otto E. Neugebauer (26 May 1899–19 February 1990)," PAPhS 137 (1993) 137–165. See further Paul Keyser, Biographical Dictionary 439–444, and Pingree's own brief necrology, "Otto Neugebauer, 26 May 1899–19 February 1990," Isis 82 (1991) 87–88.
[199] We cannot identify the precise edition. For an English translation, see The Brihat Jataka of Varāha Mishra, transl. Usha and Shashi (New Delhi 1977).
[200] The Nagari script is essentially an early form of the Devanagari script, which is still used in modern Indian.
[201] Pandurang Vaman Kane (1880–1972), author of the fundamental History of Dharmasastra I–V (Poona 1962–1975); the epilogue to vol. V.2 contains an autobiography (available online at http://www.payer.de/ dharmaśāstra. /dharmash01.htm).

that had been copied for him from the unique Kathmandu manuscript of Sphujidhvaja Yavanajātaka (Horoscopy of the Greeks).[202] *The final chapter of this manuscript is on astronomy, and I recognized in it the characteristics of Babylonian science. This discovery led to my meeting with Neugebauer on my return to America.*

From 1960 till 1963 I was a member of the Society of Fellows at Harvard, where I undertook to learn Arabic by working through a manuscript of ʿUmar ibn al-Farrakhan's translation of the Pahlavi version of Dorothy's of Sidon's astrological poem and started to accumulate the lists of relevant manuscripts, books, and articles on the exact sciences in Sanskrit that form the original basis for my Census of the Exact Sciences in Sanskrit[203] *I also spent one day each week in Providence working with Neugebauer, E. S. Kennedy, A. Sachs, A. Aaboe and others to discuss problems in ancient astronomy, and began visiting the Institute for Advanced Study in Princeton to work with Neugebauer on the Pancha Siddhantika of Varāhamihīra*[204] *and to gather information on the astronomical and astrological manuscripts at the University of Pennsylvania, Columbia, and Harvard; I continued to spend summers at the Institute through most of the 1960s. My work on the astronomical manuscripts has led to numerous publications (about a dozen) on Sanskrit astronomical tables, another neglected field.*[205] *In 1963 I joined the faculty of the University of Chicago in the Oriental Institute and the Departments of Near Eastern Languages, South Asian Languages, and History. There I began to familiarize myself more with the Mesopotamian traditions learning especially from B. Landsberger, Leo Oppenheim, and E. Reiner. I have collaborated on several publications in Akkadian with Reiner and with a frequent visitor to the Institute, H. Hunger*[206]

I went to the American University of Beirut in Lebanon for the academic year 1964–65 on a grant from the National Science Foundation. There I worked on Arabic astronomy and astrology with E. S. Kennedy; half-dozen editions of Arabic texts resulted from this collaboration.[24207] *I also acquired micro-films of numerous manuscripts in the Near East. In the summer of 1965 I spent several months in India on a grant from the American Philosophical Society visiting libraries throughout the subcontinent obtaining information about and copies of astronomical and astrological manuscripts.*[208] *In Madras I met with the eminent Sanskritist V. Raghavan,*[209] *from whom I learned of two large collections of manuscripts in the Wellcome Institute in London and at the Indian Institute Library in Oxford. I have published*

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[202] *See The Yavanajātaka of Sphujidvaja I–II, edited, translated, and commented on by D. Pingree (Harvard Oriental Series 48 [1978]).*

[203] *D. Pingree, Census of the Exact Sciences in Sanskrit. Series A I–V (Philadelphia 1970–1994).*

[204] *See D. Pingree and O. Neugebauer, The Pañcasiddhāntikā of VarāhaMihīra I–II (Copenhagen 1970–1971).*

[205] *See Pingree's bibliography at Charles Burnett, Jan P. Hogendijk, Kim Plofker, Michio Yano (eds.), 'Studies in the History of the Exact Sciences in Honor of David Pingree' (Islamic Philosophy Theology and Science). Texts and Studies 54 [2004]) 863–881.*

[206] *Erica Reiner and David Pingree, Babylonian Planetary Omens I–IV (Malibu 1975–1981, Groningen 1998, Leiden/Boston 2005).*

Hermann Hunger and David Pingree, MUL.APIN. An Astronomical Compendium in Cuneiform (Archiv für Orientforschung Beih. 24 [1989]); and Astral Sciences in Mesopotamia (Handbuch der Orientalistik I 44 [1999]).

[207] *Books by Edward S. Kennedy and David Pingree: The Astrological History of Māshā'allāh (Cambridge [Mass.] 1971); The Book of the Reasons behind Astronomical Tables (Delmar 1981); articles: Fuad I. Haddad, David Pingree, Edward S. Kennedy, "Al-Bīrūnī's Treatise on Astrological Lots," Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften 1 (1984) 9–54 (representative. in E. S. Kennedy, Astronomy and Astrology in the Medieval Islamic World [Alders hot 1998] no. XV).*

[208] *Much of that research became part of the later publication: D. Pingree, Jyotiḥśāstra. Astral and Mathematical Literature (A History of Indian Literature VI.4 [Wiesbaden 1981]).*

[209] *Venkataraman Raghavan (1909–1978).*

catalogues of about 600 Jyotiṣa manuscripts at Oxford and 1000 of the Wellcome; a catalogue of about 1000 manuscripts on Dharmasastra manuscripts at Oxford is almost completed.

In 1968–69 I was a Member of the Institute for Advanced Study in Princeton… In 1971 I joined the faculty of the Departments of the History of Mathematics[210] *and of Classics at Brown, where I have been ever since. I was asked in 1972 by E. Gombrich of the Warburg Institute to take over the edition of the Latin translation of the Arabic Ghayat al-Hakim, known as the Picatrix, that A. Warburg had become interested in the early twentieth century. This text was eventually published, as were several related texts including the fragments of the Old Spanish version and an independent Latin version of one of the Ghaya's sources, the Prayers to the Planets of al-Tabari that I found in a manuscript in Firenze."*

RESPONSE (1)

This is truly an outstanding resume. But wait, when you look under the covers, it becomes obvious that there is a substantial bias consistently expressed in all his writings beginning with his assumption that the history of astronomical developments in India occurs secondarily to the comparable developments in Greece and Babylonia[211].

[210] *In 1934 when Hitler came to power the members of the Mathematische Institut at Göttingen abandoned Germany. One of their number, Otto Neugebauer, the founder and principal editor of the Zentralblatt fur Mathematik (in which all the world's publications in mathematics were reviewed), and already recognized as the world's leading historian of Egyptian, Mesopotamian, and Greek mathematics, accepted a position at Copenhagen where he had a decade previously spent a year working on linear differential equations with constant coefficients and almost periodic right-hand sides in collaboration with Harald Bohr, Niels' brother. Neugebauer continued to edit the Zentralblatt fur Mathematik while in Copenhagen, but also finished there his fundamental investigation of ancient mathematical texts from Mesopotamia, the three volumes of Mathematische Keilschrift-Texte, and conceived of the project of publishing collections of all extant and known texts on mathematics and astronomy in Akkadian, the standard Mesopotamian language in the last two millennia BCE and in Egyptian.*

When the Nazis threatened Denmark in 1939, Dean Richardson at Brown together with the American Mathematical Society arranged for Neugebauer to come to Providence to teach in Brown's Department of Mathematics and to transform the Zentralblatt into the American-based Mathematical Reviews, to be published, as it still is, by the AMS, but edited, from 1940 till 1948, here at Brown by Neugebauer.

In 1940 Neugebauer toured the country examining collections of cuneiform tablets. At Chicago he found not only tablets, but Abraham J. Sachs, a brilliant young Assyriologist whom he brought to Brown as a research assistant with the help of a grant from the Rockefeller Foundation. In 1948 Sachs, still only a Research Assistant was offered the Chair in Assyriology at Johns Hopkins in succession to one of America's foremost Near Eastern scholars, William F. Albright. Since the Department of Mathematics balked at promoting an Assyriologist to a professorial rank, Brown's then President, Henry Wriston, created the Department of the History of Mathematics for Neugebauer and Sachs, primarily as a research unit, but also with the responsibility to train highly qualified Graduate Students. The first of these were Olaf Schmidt, who continued the still flourishing tradition of the Neugebauer approach to the History of Mathematics in Denmark, and Asger Aaboe, who initiated the same tradition (now regrettably dead at his retirement) at Yale.

Another quote; "The study of astronomy pursued in India from antiquity until the introduction of the modern science, in the nineteenth century does not fit into a Western historian's, normal conception of a scientific enterprise. In particular, Western astronomy from Hipparchus till Kepler consistently emphasized the need to combine carefully planned and executed observations with theory in order to determine and perfect geometrical models that generate predictions corresponding as closely as possible to the observed phenomena. The successful pursuit of such programs of astronomical research was certainly rare but the attempts were many. In India[211] *astronomers paid little attention either to observation or to theory. It is my purpose in this paper to describe without going into technical details the Indian's approach to the celestial science, to discuss, at least some of the causes of their peculiar attitudes. To one of the effects of their failure to develop a science that could compete with that of the West. Mathematical astronomy was introduced into India along with the Sciences of divination from*

"In the 1976 article[212] I attempted to consider the origin of the Indian methods of determining the mean longitudes of the planets in the context of the history of Indian astronomy. That history shows that essentially all of the methods and many of the parameters of Indian astronomy, prior and subsequent to the fifth century CE, were derived from Mesopotamia and Greece; it also is apparent that the planetary models of the Brahmagupta, ĀryaPakṣa, and Ardharātrika Pakṣa are of Greek origin. These facts dispose me to believe that, unless it can be proven otherwise, the Indian derivations of the mean longitudes of the planets must also be supposed to be in some way derived from Greek sources.

While the Greeks had a long tradition not only of observing the planets, but of using observations to construct and refine geometrical models that permit the calculation of corrections to the planets' mean longitudes, there was no such observational tradition in India in the fifth century, nor did one develop in later times (this, of course, is not to deny that individual observations may have been used from time to time to modify parameters). The primary evidence against the claim that the Indians made careful and systematic observations is the fact that their coordinates for the fixed stars-in relation to which the planets were observed-fit no known set of stars visible in the sky; the data will be found in the relevant tables of my 1979 article. I fail to be able to imagine that the same observer could accurately determine the sidereal longitudes of the planets and not with equal accuracy determine the coordinates of the fixed stars.

The Indians' geometrical models for computing the corrections to the planets' mean longitudes, while derived from Greek sources, are crude in comparison to Ptolemy's. Billard assumes that Āryabhaţa I, independently of Greek influence, invented these models, and also, with great accuracy, determined the mean longitudes of the planets in about CE 510 on the basis of observations of their true longitudes; the reduction of the true to the mean longitudes must have been based on these comparatively crude models. I contend that the problems of finding satisfactory mean longitudes and models with their

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Celestial omens and of astrology, from the West. The earliest infusion was of simple arithmetical schemes for establishing an intercalation cycle and for determining the length of daylight derived from Akkadian sources transmitted through Achaemenid Iran and embodied in a. text called the Jyotiśa Vedanga that was composed in Northwestern India by Lagadha in. probably the late fifth or early fourth century BCE[211]. This was followed by the translation of various Greek texts on astrology and astronomy into Sanskrit in Western India in the Second, Third and fourth centuries CE. These texts expounded several different astronomical systems. One represented Greek adaptations of the lunar, solar, and planetary hypothesis during the Seleucid and Parthian[211] periods. Another seems to have been closely related to what little we know of Hellenistic astronomy and specifically to the theories of Hipparchus; and a third preserved planetary models devised by Peripatetic philosophers to solve the problem of the anomalous motions of the planets, while salvaging the Aristotelian principle of concentricity – that is retaining a fixed distance for each of the planets FROM the centre of the universe[211]. The preservation of this Greek material is one India's greatest contributions to the history of science[211]. But each of these astronomical systems was transformed in India into something somewhat different from what one expects in a cuneiform or Greek text; such transformations are only to be expected when an intellectual system is introduced into an alien culture. Fortunately, the nature of an advanced astronomical theory is such that, it cannot be altered beyond indisputable recognition; such elements as the theory of epicycles and eccentrics can only have been developed within the spoci6c traditions of Greek science, and astronomical parameters which are the result of complex interrelationships of observation and theory cannot have been independently arrived at in Mesopotamia, Greece, and India. The derivation of their mathematical models (arithmetical from the Babylonians Geometric from the Greeks) and their basic parameters from external sources, of course explains the lack of concern with observational astronomy in India. By this I do not mean that there was no interest in looking at the stars and planets, but that there was no tradition of ' systematic observations designed to test and improve theory nor any tradition of …"

[211] David Pingree's reply to Vander Waerden 'Two Treatises on Indian Astronomy' , x1,980, pp.50-62

[212] See endnote 40 in Prologue

parameters from observations made within one lifetime are sufficient to render Billard's hypothesis impossible; I further suggest that, if Āryabhaţa I were responsible for both, he should have found models and parameters for them of a quality commensurate with that of his mean longitudes. I believe that van der Waerden agrees with me; for he supposes that Āryabhaţa I had at his disposal tables of planetary motions."

RESPONSE (2)

1. He keeps repeating this opinion, ad nauseum, in every paper that he writes, with great vehemence, without citing a single instance of documentary evidence in the shape of a translation from Greek to Sanskrit. His explanation that they got it from the Babylonians is just an assertion without a corpus delicti or a smoking gun. Making such an assertion is an exercise in Tautology. He cites various texts in Sanskrit (Yavanajātaka, Paulisa, and Romaka Siddhānta) as evidence of Greek sources. His assumption is that these were Greek sources. But at the end of the day these are Sanskrit texts, which display none of the peculiarities of Ptolemy's work and nowhere has he proven there were corresponding Greek sources and shown us the documentary evidence that there are extant Greek texts, and if you assume the answer to your (whether it is geometry or historiography) problem, he should know there is nothing left to prove.

2. His remarks that the Indics did not have an observational tradition in Astronomy make very little sense. How does he expect them to have come up with such accurate measures long before the Greeks did? The Greeks were not even interested in Sidereal measurements and did not understand their significance. Hipparchus is supposed to have understood the concept of a sidereal year, but he shows no evidence of knowing what to do with the Sidereal data. One has to wait for 1800 years for the likes of Leonhard Euler to find another Occidental to have realized the significance of a sidereal year. The unfortunate part of the story about Hipparchus is that none of his works except one, the Commentary on the work of Aratos and Eudoxus, is available today and yet we are told that Greek observational tradition was far superior to that of India. Most of the statements about the Work of Hipparchus are unverifiable as there is no corpus delicti.

3. Pingree becomes a prisoner of his own beliefs that nothing worthwhile happened in India, other than as a derivative civilization. We need to digress here on the establishment of the antiquity of the Veda.

4. The vast majority of the Indologists working on India exhibit this tendency and do not either understand that the dating of the Vedas by Max Müller was a terminus ante quem date or the latest possible date or deliberately choose to ignore the caveat that Max Müller himself said categorically that no power on earth could determine, in his view, when the Veda was written. In fact the tenacity with which the Occidental uses the terminus ante quem date gives his game away, namely his only interest in Indian history was to push the date forward as much as possible and then conveniently forget this was a terminus ante quem date. Of course Max Müller was dead wrong as we have shown in Chapter VII. Furthermore, the resolution of such an Astro-chronological approach is no worse than Radiocarbon dating

5. The ignorance that Historians in the mathematical sciences display about the Chronology of India is only exceeded by their hubris in not accepting the authentic antiquity of Ancient Indian astronomy as enunciated by the Indics themselves. Why do we say this? The major reason to accept the chronology of the Purāṇas, is the evidence provided by the Paleo-

channel (traces of the ancient river courses) of the Sarasvati river.[213,214] So the conclusion is inescapable that the Vedic texts were compiled into metrical verse long before 3000 BCE when there is ample evidence that the long drawn process of the drying of the Sarasvati has already begun. and the references to the Nakṣatras and the Rāṡi were made a long time before the Greeks enter the picture, There is further corroboration of this in the Astronomical observations made in the Ṛg as well as in latter texts such as the MBH[215]. The Rāmāyaṇa also contains numerous observations indicating that it was first composed by Vālmiki before the end of the Vedic period. We have collated all these observations in the chapter on Archeo-astronomy and Astro-chronology.

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"***To supplement Ptolemy's accounts of the work of Apollonius, Hipparchus, and other early Greek astronomers, historians have had to rely on disparate and often desperate sources****;…****However, one of those civilizations that was profoundly influenced by Greek culture has preserved a number of texts (composed in the second through seventh centuries AD) that represent non-Ptolemaic Greek astronomy. This civilization is that of India, and the texts are in Sanskrit. It is certain that Greek astronomical texts were translated into Syriac and into Pahlavi, as well as into Sanskrit, but of the former we still have but little, and of the latter almost nothing; and in both cases we must rely for much of our knowledge on late accounts in Arabic****…****These techniques as preserved in the Sanskrit texts were certainly not invented in India, which lacked the astronomical tradition necessary for their development****. Nor were they introduced directly from Mesopotamia since they first appear, in a crude form, in the* **Yavanajātaka, which is based on the translation of a Greek text made three-quarters of a century after the last dated cuneiform ephemerides was inscribed**[216]*. The full forms of these techniques are found in India only in texts, the Vaṡiṣţa and the Paulisa, of the third or fourth century which represent translations of Greek texts other than that translated by Yavaneṡvara. The pa*pyri, *Geminus, Vettius Valens, and the three Sanskrit texts all attest to the popularity of this Greco-Babylonian astronomy in the Roman Empire in the first three or four centuries of our era."*

RESPONSE (3)

It is not uncommon to come across sentiments such as the above where the certainty expressed in a transmission from the Occident to India is inversely proportional to the evidence of such a transmission. In other words, Greece which left behind a very meager literary legacy in Astronomy, had a bountiful astronomical tradition, whereas the Indics who have provided a veritable cornucopia of literary treasures, so much so that he was compelled to call it a census (in five volumes, no less) lacked an astronomical tradition. We find this statement stunning, when we pause to ponder on the extent of its cognitive dissonance. It is doubly insulting to the ancient traditions of the Indic civilization that not only is there no credit for the uniqueness and antiquity of this tradition, but the resulting work of the Indics is used to decipher the Greek past.

David Pingree leaves behind a legacy of missed opportunities, where he could have made a more honest assessment of the Indic contributions. To be regarded as an intellectual at a global level, as a minimum one must eschew the beguiling assumption that the 'other 'is inferior simply because he is not

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[213] *Frawley, David and Navaratna Rajaram "Hidden Horizons", Publishd by Swanminarayan Akşarpith, Amdavad, 12007*

[214] *see Glo-pedia entry on RV* ऋगवेद

[215] *op cit endnote 62*

[216] *Note how cleverly he converts an opinion into a fact. Where is the evidence that the Yavanajātaka was translated from the Greek*

one of ‘us’. As it stands, his credibility remains severely compromised and it is accurate to say that the stance he has taken towards Indic astronomy is similar to that of Hegel when he referred to India as a cultural cul de sac from which nothing original emanated. This is far more reprehensible in the case of Pingree, since he was better informed than Hegel was about the relevant Sanskrit literature, and could not plead ignorance of Sanskrit as an excuse.

This is not to say that no transmission took place from Greece to India. There is a stronger case to be made that there was transmission of Astrological material, but again there is very little to bite on since there are no documents that exist in both Greek and Sanskrit that attest to such an event, namely the transmission from Greek to Sanskrit. In CE 150 an Astronomer by the name of Yavaneṡvara is reported to have translated into Sanskrit a Greek Astrological text, which was written in Alexandria. If he wrote it in Sanskrit, he can hardly be regarded as being Greek. However, nobody can pinpoint the original for this document in Greek. The **Yavanajātaka** (Sanskrit: *Yavana* 'Greek' + *jātaka* 'nativity') of **Sphujidhvaja** is an ancient text in Indian astrology where Sphujidhvaja alludes to this in his writings. But again this is very vague and does not spell out what was borrowed from Greece. It appears this was primarily a text on Greek astrology and therefore had very little impact on the mainstream astronomical developments in India. The most that can be said is that Greek Astrology (not Astronomy) influenced the Indics into adopting Astrology as a tool for the divination of the future, where previously it may have been used primarily as a calendrical device to predict seasons and eclipses based on periodicities. The evidence even for this meager borrowing from Greece is not borne out by the chronology of the Vedas.

In the end, it appears that the Occidental cannot break himself loose from the stranglehold of the notion that all science is Western in Origin and that any contribution from non-Western sources must be treated with suspicion, unless they are tied civilizationally to the west. The notion that the Occident must be credited with every invention and development known to the human species is evidence of a pathology that makes any dialog on the subject extremely difficult. This debate over temporal priority, is not of the choosing of the Indic, but is entirely a consequence of the pathological obsession of the Occidental to claim priority over every aspect of every field. The lifetimes that several Indologists from the Occident have spent denying the Indic the priority in such matters, are a digression from more pressing areas which need attention, but now that the gauntlet has been thrown by the Occident, the Indic should carry it through until the truth is accepted. It is simply not a credible posture on the part of the Occidental to ask the Indic to accept that a particular tradition is nonexistent in India when at the same time the same investigator spends a goodly portion of his life studying the very same non-existent tradition

It is the responsibility of the modern Indic to be more proactive in understanding the past and not be intimidated by the Occidental when he belittles the Indic contribution, especially in those instances where the evidence is overwhelming that the Indic has temporal priority. It is particularly apropos to shed the image that the Indic has acquired (whether justifiable or not) that he has historically been lackadaisical about chronology. This is accentuated by the Occidental claims that Indics have not been good historians, while at the same time accusing the Indic of Hindu nationalism when he attempts to correct the widespread non *sequitur* that have accumulated under the deliberate misdirection of the colonial power as he revised the Indic history which I have summarized elsewhere under the Title of Colonial Paradigm of History[217]. Such a perception encourages the Occidental to make even bolder claims, with the final conclusion, as has been explicitly stated by Rouse Ball that the only good work that was done in India was with the advent of the mythic *Ārya*ns and when their genetic strain became

[217] Vepa, Kosla „Colonial Paradigm of History" Proceedings of seminar held at WAVES conference , Florida, June 2008

diluted, nothing worthwhile happened thereafter[218]. We will consider first the case of transmission from Greece to India before we tackle the specific instances, such as Euclid and Ptolemy.

GREECE AND INDIA IN THE ANCIENT ERA

The Greeks occupy a special place in the hagiography of Europe and indeed of the Occident as a whole. All the architectural icons related to their heritage, in use in Europe and the new world are patterned after the Greeks or the Romans. Some countries in Europe, especially Britain view themselves as the legitimate inheritors of the Greek heritage and have made the study if Greece and the Greek language an important part of their education in the classics, and have closely linked their heritage with that of the Greeks.

The Semitic and Mediterranean world had ubiquitous contacts with the Indic. We are in the long drawn out process of researching this phase of Indology. Our knowledge of the facts, are meager at the moment. But the more we learn about the Greek Savants who for the most part hailed from Asia Minor, like the Trojans of Homer, the more it is apparent that they learned a lot of their sciences from others including the Indian subcontinent.

This came to a virtual stop during the heyday of the Roman Empire when it became the paramount Mediterranean power after the fall of Carthage. Rome remained a major trading partner of India but ceased to be interested in Indic scholarship. Even though the Byzantines or the Eastern Roman Empire centered in Constantinople was primarily Greek or Ionian in its cultural leanings, it is a reality that they ceased to evince interest after the advent of the adoption of Christianity, as India came to be associated increasingly with the Pagan practices that they were trying hard to extinguish in Europe.

Let us follow the story of the Greek and Indian contributions of Mathematics as recounted by the late Abraham Seidenberg in his landmark publications on the Origin of Mathematics[219] and the Ritual origins of Geometry[220]. Seidenberg comes to the conclusion that there are 2 great traditions in Mathematics. These are the geometric or constructive (tradition I), and the Algebraic or computational (traditional II). He proposes that both these traditions have in fact a single source. One has to go back to the work of Otto Neugebauer[221], who is the first amongst the Occidentals to admit that most of the Greek contribution can be traced to Babylon. Unlike most in the west who studied the history of Mathematics, he was aware of the Sulva Sūtras, through the translations of George Thibaut. George Thibaut, was one of the very few among the Galaxy of British, French & German Indologists who had some familiarity with Sanskrit (this list includes Colebrook, Whish, Jacobi) and who were also competent to translate mathematical texts. Like most occidentals, Neugebauer foresees all kinds of difficulties when it comes to postulating a technology transfer from India to Greece (but not vice versa). To quote Neugebauer "the difficulties, involved in the view of a direct borrowing by the Greeks from India fall away on the assumption of a common origin in Babylonia". To this Seidenberg remarks drily that "This is really an excellent suggestion, and the only trouble with it is that many of the elements of Greek and Indian mathematics, especially the geometric construction at issue, are not found in old Babylonia." The

[218] *see endnote 26 in Prolog*
[219] *Seidenberg, A., "The origin of Mathematics" Archive for History of exact Sciences, vol. 18 (1978), pp. 301-342;*
[220] *Seidenberg, A., "The ritual origins of geometry" Archive for history of exact Sciences, vol. 1 (1962), pp.488-526*
[221] *Neugebauer, O. "The exact sciences in antiquity, published by Dover, 1969.*

monumental work of Neugebauer changed the conceptions of the origin of mathematics and clearly established the precedence of Babylonian Mathematics over that of the Greeks. However as we shall see, there was still the unanswered question of the precedence of Babylonian over Indian mathematics, but it was crystal clear, the old notion that all mathematics originated in Greece, was buried for good.

Then there is also the reluctance to admit that the Indic tradition does not favor tradition I over II or vice-versa and if they were perceived to have favored the algebraic approach, it is only because of the greater competency that they subsequently developed in Algorisms. This is in stark contrast to the situation in Greece where they did not have the embarrass de riche, of having an alternative to geometry lacking as they did in elementary skills in manipulating numbers. In any event, the irony in the stance of Occidentals sticks out like a sore thumb. While they are willing to grant the ancient Indic, the accolade of imbibing the knowledge the source of which is 2000 miles away, they are unwilling to grant him the capability of having invented these disciplines within the confines of the Indian subcontinent.

When comparing the rival claims of precedence between those of Greece and the Indologists, Seidenberg notices that in reality there is no such rivalry, for the simple reason that the later are even more allergic to press the claims of Indic Mathematics, than are the experts in Greek mathematics such as Cantor. In fact they are even more dogmatic that no precedence should be given to Indic mathematics, and that no date be assigned to Indic mathematics prior to the Golden age of Greece beginning with Thales of Miletus.

Thus Seidenberg concludes that the Sulva Sūtras are a unique development and do not owe anything to an Old Babylonian Heritage. But he was hobbled by the insistence of the Occidental Indologists that the *Arya*n Invasion Theory is a fact and is therefore reluctant to make a definitive statement that the common source of all mathematics in the planet are the Sulva Sūtras and contents himself by saying that such a source is very much like what we see in the Sulva Sūtras. Had he been reassured that the Sulva Sūtras were composed approximately in 2000 BCE, he would not have had any reservations in making the statement with a greater degree of certitude, if you follow his logic. This is merely one example of what a scholar faces in the West when he tries to oppose the conventional view that India borrowed much of her mathematics from Greece. But it is increasingly clear that if one reads the 2 contributions carefully, the independence of the Indian contributions is unmistakable.

CULTURAL DIFFUSION BETWEEN GREECE AND INDIA

Much has been made by the Occidental of the impact of Greek mathematics and astronomy on the development of these topics in the Indian subcontinent. Almost every scientific development in India in these fields has been minimized as being derived from Greece. This is very curious for at least a couple of reasons. First there is no record in the Indic narrative of any borrowing of technology or mathematics from Greece or in fact anything about Greece, The second reason, which is a clinching argument and does not allow for any ambiguity regarding the prior contributions of the Indics, is that the date when the developments took place in India, is far earlier than those of Greece at which time the Greek civilization had barely begun its journey to brilliance.

While there are fairly numerous instances of Greeks mentioning India in their writings, it is rare to find mention of any Greek in any Indian manuscript including the most famous Greek of them all, Alexander, the very same who was purported to have invaded India. Every Occidental with few exceptions would rather alter the dates at which a development occurred in India and assign it a date later to that of the Greeks than admit that the development was unique to India. The very thought that their much ballyhooed Greek heritage owed a lot to India was so absurd and so painful for their egos that they

would not even entertain that thought for fear that the verdict would go in India's way. It is this Occidental obsession to give the Greeks the preeminent position in antiquity that has resulted in the fact that there are very few dates assigned in Indic History prior to 600 BCE.

We will begin our story in the Island communities of the coast of Asia Minor such as Miletus and Samos where Greek scientific endeavor flourished. These city states were populated by Ionian Greeks similar to the Trojans who were immortalized by Homer in his 2 epics, the Iliad and the Odyssey. It is in these city states that the Greek contributions to mathematics took root. But the Greeks were not operating in a vacuum; they were preceded, as we have already asserted, by a long tradition of scholarship in Mesopotamia and Egypt, not to mention India and China. So, the Greeks were relative latecomers on the scene and it is only the ignorance of the Occidental, abetted by his prejudice that led them to think that all science originated in Greece, in the islands off Asia Minor, in cities such as Miletus and Samos.

THE CASE OF THE ELUSIVE EUCLID

The Elements of Euclid can rightly be classified as one of the most recognizable book titles from the Ancient Era and is considered part of the immense legacy left behind by Ancient Greece from the era before Christ was born. It has been a revelation that none of this is true. We know nothing about Euclid and there is serious question as to whether there ever existed a person by the name of Euclid who wrote such a book. An equally important matter is the date when the first edition of Euclid's Elements was published. We examine the facts to see wherein lays the truth.

There is no mention of Euclid in the earliest remaining copies of the *Elements*, and most of the copies say they are "from the edition of Theon"[222] or the "lectures of Theon", while the text considered being primary, held by the Vatican, mentions no author. The only reference that historians rely on, of Euclid having written the *Elements,* was purportedly from Proclus, who briefly in his *Commentary on the Elements* ascribes Euclid as its author. However, the actual source of this important clue is a manuscript called the Monacensis 427. I am indebted to the compilation by CK Raju in his CFM, where he goes on to make the further inference that "*Since the Monacensis manuscript is on paper and since paper mills started in Europe only after the 13th or 14th century CE, the manuscript is from a later period … but has been dated with the usual optimism to earliest horizon of the 10th century CE. Thus our key source of information about Euclid is the above vague remark from an undated manuscript which comes realistically from 1600 to 1900 years after the time that Euclid allegedly lived."* This Anumāna by C.K. Raju is indeed the nail on the coffin for the proposition that there was a Euclid. So what we are left with is a Theonine document of the 4th century, rather than a Euclid's Elements of the 2nd century BCE.

[222] *Theon of Alexandria ,Theon (Greek: Θέων, ca. 335 - ca. 405 CE) was a Greek scholar and mathematician who lived in Alexandria, Egypt. The biographical tradition (Suda) defines Theon as "the man from the Mouseion"; actually, both the Library of Alexandria and the Mouseion may have been destroyed a century before by the Emperor Aurelian during his struggle against Zenobia. Some scholars think that they were closed by the patriarch Theophilus on order of the Christian Roman emperor Theodosius I in 391 CE. Theon was the father of the mathematician and pagan martyr Hypatia of Alexandria whose murder is attributed by Socrates Scholasticus to "political jealousy" which instigated mob violence. Theon's most durable achievement may be his edition of Euclid's* Elements*, published around 364 CE and authoritative into the 19th century. The bulk of Theon's work, however, consisted of commentaries on important works by his Hellenistic predecessors. These included a "conferences" (Synousiai) on Euclid, and commentaries (Exegesis) on the Handy Tables and* Almagest *of Ptolemy, and on the technical poet Aratus.*

We quote Constance Reid[223] "*We have no copy of the original work. Oddly enough we have no copies made even within one or two centuries of Euclid's time (circa 200 BCE). Until recently, the earliest known version of the Elements was a revision with textual changes and some additions by Theon of Alexandria in the 4th century CE, a good 6 centuries after the nonexistent Euclid purportedly compiled it in Alexandria. The traditional text book version of the Elements, almost completely, until very recently without change, was based of course, on the text of Theon. …. when we say Euclid says, "**We are speaking of a compiler much closer to us than the original compiler of the Elements***"**.** Furthermore we may not even be speaking of one person but an entire tradition that had accumulated at the Library in Alexandria and if that was the case it would be a misnomer to say that Geometry was a legacy of Hellenic Greece.

The reasons why the Vatican (it was not known as the Vatican in those days) did not want to publicize the fact that the version of the Elements that was current in Europe was due to Theon and his daughter, is not entirely clear to us although one can speculate based on the writings of that period. It also explains why the existence of Euclid is so important to the Occidental. The notion that Euclid was the author made it easier to accept that they were indebted to the pagans for their learning, for the simple reason he was supposed to have lived prior to the advent of Christ. It is probable that the Vatican balked at the prospect of ascribing the Elements to Theon and his daughter, Hypatea given the brutal manner in which they had her killed.

> Claiming a prior antiquity made it that much easier to claim that the tradition of Geometry was purely a result of scholars in the Occident. Most Occidental historians are not willing to make the rational inference, that a 4th century text in Geometry would have available all the knowledge that was accumulated in Alexandria and could not be considered solely a Greek achievement. This brings us to the question of the origins of the library at Alexandria which we will examine in the next section. The dating of Euclid's Elements to the 4th or 5th century of the Common Era has a significant impact on the probable direction of the transmissions that took place and is potentially tied to the fate of the Alexandrian Diaspora. It appears that the Diaspora congregated in Jundishapur in Persia of the Sassanids.

THE INDIC UNIVERSITY TRADITION

The Indic University Tradition was supplementary to the Vedic Pātashāla system where a student imbibed all that he needed to understand the Universe around him as well as the requirements for commerce, agriculture. The university system catered to those who were higher in the Maslow hierarchy of needs. The Entire Indo Gangetic Plain was studded with Pātashāla's and Viśvavidyālaya's. The Pātashālas were small in size and were run in a Guru Parampara tradition. The typical curriculum included the Vedic Episteme (including Nyāya (Logic), Vyākarana (Grammar), Chandas (Prosody), Shabda, the Knowledge of Riṣis (Seers), Jyotiṣa or Nakṣatra Vidya (to determine time, direction and Place), Gaṇita (Mathematics and Algorismus), Semantics and Linguistics.

The famous universities (Viśvavidyālaya's) were Nalanda, Vikramṣīla, Odantipura, and Takśaṣīla. There is more than enough irony in the fact that the University system was pretty much destroyed by the Turco Afghan Islamic hordes circa 1200 CE about the same time that the English started building Cambridge University. So India entered the 2nd Millennium of the Common Era handicapped by the loss of its higher education system and had to rely solely on the Pātashālas, which were run in the neighborhood by the Pandits. These were usually supported by the Raja of the region. By the 19th century even this limited

[223] *A long way from Euclid' , New York, 1963*

support had stopped courtesy of Macaulay when he made English education mandatory. The direct result of this was a vast increase in illiterates, and by 1900, the literacy rate in the subcontinent was hovering around 6%. So, when David Pingree opines that there is something lacking in the Indic system that resulted in a "*failure to develop a science that could compete with that of the West"* he ignores the fact that India was no longer master of its own destiny, and that the British either through incompetency or malice unleashed a steady series of famines in India. A man without food in his belly will not likely be thinking about the Inverse Square Law of Gravitation. The Colonial power had obviously no intention of fostering an education in India that would question his superiority and his self-imposed custodianship over an ancient civilization. Again, the intent is not to shift the blame for Indic's lack of competitiveness in the 20th century science, to actions other than their own, but to point out that the inference that he (Pingree) makes that the current lack of competitiveness implies that India borrowed from the Greeks in the past, is not borne out by the facts of the case or the realities of the subcontinent. The reality of the situation was that Indian science was competitive till the mid-18th century and it was the actions of the colonial overlord, who turned the vast subcontinent into a Gulag, almost as big in size as Siberia from which few could escape and into which he was careful enough to exclude all notions of civilization including the elementary rights of an individual. The astonishing fact is that despite these adverse conditions India was able to produce world-renowned scientists and astronomers such as the late Nobel Laureate Subramaniam Chandrasekhar. It was said[224] of him "There is total unanimity among astronomers that Chandra, as a Mathematical Astrophysicist, was the greatest of our generation." Clearly David Pingree was ill informed about the development of the sciences in current day India.

THE ACADEMY OF JUNDI-SHAPUR

The **Academy of Jundishapur** was a unique institution that benefited from two events in the decaying Eastern Roman Empire. The first event occurred when the East Roman Zeno Isauricus (d. 491) closed the school at the Syrian city of Edessa (Al-Ruha) following the condemnation of its scholars by the bishop of the city as Nestorian heretics. Thus, in 489 CE the expelled philosophers wandered the Arab and *Arya*n lands of the Middle East, eventually finding refuge in **Jundishapur** in what was then the Persian Empire. Hence it was, that the Nestorian Centre of learning moved from Syria to Jundishapur in Persia, and there the Nestorians established a large hospital.

"IT IS MORE THAN ENOUGH [FOR THEM] MERELY TO BE ALIVE."

The second consequential event occurred when Emperor Justinian (*c*.482-565 CE) prohibited the operation of the ancient Greek schools of philosophy within his empire in response to the stiffening bigotry of organized Christianity. Justinian was, unlike his predecessors, determined to convert the entire population of his empire over into Orthodox Christianity. He refused to allow vestiges of paganism to remain in his lands and vigorously acted to destroy them. He declared on the subject of the pagan Greeks: "one finds persons possessed by the error of the unclean and abominable Hellenes, and performing their practices, and this arouses in God, in his love for mankind, a righteous anger." Consequently he issued the following decree in the 530s, which effectively ordered the entire population TO convert to Orthodox Christianity.

FIGURE 1 EMPEROR JUSTINIAN

[224] *Martin Schwarzschild, a professor of astronomy emeritus at Princeton University. http://www-news.uchicago.edu/releases/95/950822.chandrasekhar.shtml*



"All those who have not yet been baptized must come forward, whether they reside in the capital or in the provinces, and go to the very holy churches with their wives, their children, and their households, to be instructed in the true faith of Christians. And one thus instructed and having seriously renounced their former Error let them be judged worth of redemptive baptism. Should they disobey, let them know that they will be excluded from the State and will no longer have any rights of possession, neither good nor property; stripped of everything, they will be reduced to penury, without prejudice to the appropriate punishments that will be imposed on them."

As part of Justinian's religious campaign to suppress the last vestiges of paganism and heresy, he ordered the closure in 529-532 CE of the Platonic Academy in Athens, which had dated back to the 4th century BC. As the professors were paid from inheritances from donors, as opposed to state pensions, they had survived earlier suppression attempts such as the Roman conquest of Greece, and the later early Christianization. Violent uprisings and riots followed the closings, which Justinian put down harshly. Justinian reaffirmed his decision, stating of the pagan heretics that:

"It is more than enough [for them] merely to be alive."

THE FOUNDING OF THE LIBRARY OF ALEXANDRIA AND ITS IMPACT ON KNOWLEDGE TRANSMISSION

There is no dispute that the Library at Alexandria was one of the wonders of the Ancient world. Alexandria was founded in Egypt by Alexander the Great. His successor as Pharaoh, Ptolemy II Soter, founded the Museum or Royal Library of Alexandria in 283 BC. The Museum was a shrine of the Muses modeled after the Lyceum of Aristotle in Athens. The Museum was a place of study, which included lecture areas, gardens, a zoo, and shrines for each of the nine muses as well as the Library itself. It has been estimated that at one time the Library of Alexandria held over half a million documents from Assyria, Greece, Persia, Egypt, India and many other nations. Over 100 scholars lived at the Museum full time to perform research, write, lecture or translate and copy documents. The library was so large it actually had another branch or "daughter" library at the Temple of Serapis. The question is how such a large number of these documents got to Alexandria from such distant places so suddenly. It has been reported in the Zoroastrian Book of Nativities that Alexander had stolen ancient sciences from the Persians. "For when Alexander conquered the Kingdom of Darius the King, he had all the books translated into the Greek language. Then he burnt all the original books, which were kept in the treasure houses of Darius, and killed everyone whom he thought, might be keeping any of them. Except that some books were saved through the protection of those who safeguarded them[225]."

It is therefore entirely likely, although we do not claim the same degree of certitude as did David Pingree for transmission in the reverse direction that Indian astronomy was available to the Alexandrians shortly after the establishment of the library in 280 BCE. Notice that there was not much to transmit from west to east during this period, especially in the field of Astronomy.

THE CASE OF PTOLEMY

[225] *Gutas , D, Greek thought, Arabic Culture, the Greco Roman Translation movement in Baghdad and early Abbasid society (2nd to 4th, 8th to 10th centuries), Routledge , London, 1998*

There are similarities to the story of Euclid in the case of Ptolemy, but the story is far more complex. Claudius Ptolemy was a Roman citizen in Alexandria during the 2nd century. Alexandria had passed into Roman control and became a province of the Roman Empire after the battle of Actium on 2nd September 30 BCE where Mark Antony and Cleopatra were defeated by Octavian .We do not know whether he had a different name but the Arabs referred to him as Batlaymus. Even 400 years after its founding in the late 3rd century BCE, the Library of Alexandria was recognized as a great institution of learning, and Ptolemy was its resident during the Golden era of Alexandria. This was an exciting time for science in Egypt. And yet there is no record of the birth or death of this individual. Nor are there extant manuscripts of his works. He is reputed to have written 4 books namely;
The Syntaxis Tetrabiblos Geographia Planetary Hypothesis.
Even if we do not know the identity of the author or the exact date when he lived, it remains true that the Syntaxis is a major work advancing our state of knowledge of Astronomy, if we accept that it is equivalent to the Almagest which appeared 8 to 9 centuries later. The identity of the author does not matter as long as the content is meaningful. The mistakes made in the Syntaxis are part of the process by which humankind expands its store of knowledge. But the date when it was written makes a great deal of a difference The Occident has gone to extraordinary lengths to date the original Syntaxis around 150 CE, without addressing the problem of finding the latest possible date when it could have been written and if there were accretions, when and who made the accretions .There has been no evidence of a vulgate text during the first millennia of the common era. Some points to be made about Ptolemy's Syntaxis;

1. There is no way of determining the difference between the Almagest which is mainly a 9th or 10th century Islamic era document and the Syntaxis which is claimed to be a 2nd century document.

2. There is epistemic discontinuity between what transpired prior to the date when Ptolemy's Syntaxis is purported to have been written, and after Ptolemy there is a void in the entire occident on matters relating to Astronomy. This is an instance of an epistemic discontinuity that is almost always present when there is assumption of a new paradigm accompanied by incomplete understanding. We direct the attention of the reader to the book by Dr. Sudhikant Bhardwaj[226]on the similarities and distinctions coupled with the extensive discussion in this and in the prior chapters and let the reader decide whether the similarities are more dominant than the distinctions to warrant ON's fundamental assumption that independent development of the 2 systems was highly unlikely. My suspicion is that ON would not be as dogmatic in this assertion, should it be accepted that chronologically Indians have priority.

3. There is the issue of how Ptolemy was able to do arithmetic with large numbers when by his own admission; he had difficulty with fractions (see Prologue chapter, endnote 33).

4. There is also the issue of accuracy of the tables in the Almagest. Then there is the issue of Ptolemy having doctored the data[227] to match his results. This is neither the first nor the last

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[226] *Bhardwaj, Sudhikant Sūrya Siddhānta, P.40-49,, section 1.7, Sūrya Siddhānta and Greek influence*
[227] *Newton, RR, Robert Russell Newton, also R. R. Newton (July 7, 1918 - June 2, 1991) was an American physicist, astronomer, and historian of science. Newton was Supervisor of the Applied Physics Laboratory at Johns Hopkins University. Newton was known for his book The Crime of Claudius Ptolemy (1977). In Newton's view, Ptolemy was "the most successful fraud in the history of science". Newton showed that Ptolemy had predominantly obtained the astronomical results described in his work The Almagest by computation, and not by the direct observations that*

time that a scientist would have been accused of having done such a deed[228]. However, we feel, that the fundamental issue at stake here is the dating of the Syntaxis itself, because, unless it is established conclusively that the text has been authored in the 2nd century CE, the question of the origin of the data is moot.

We believe for all the above reasons, that the use of epicycles (not to mention the ability to do algebra and trigonometry, which the Greeks lacked during that period) was borrowed by the Greeks (via Babylon) from India.

But it remains an interesting artifact that if one were to hypothesize that the Indics had indeed plagiarized from the Greeks, as almost every historian of mathematics vociferously proclaims, that there is no mention of Ptolemy's Lunar theory and there is a significant difference between the Indic approach for the inferior planets in the case of Ptolemy.
Undoubtedly the most perceptive astronomer prior to Ptolemy was Hipparchus, who was primarily an observational astronomer. However, contrary to the opinion of most and with the exception of Hipparchus, the Greek tradition in observational astronomy was in large part the inheritance of the work of others who preceded them including the Babylonians and the Egyptians. As we have mentioned there is a very strong probability that they had access to the Sūrya Siddhānta, via Jundishapur (the library that was looted by Alexander and transplanted into Alexandria) which we believe from internal evidence to have been composed between 400 and 500 BCE. So Ptolemy did not have a strong Greek tradition in Astronomy to lean on, and if he lived and wrote the Syntaxis in the 2nd century CE, it is doubtful whether he had the mathematical pre-requisites to grasp the analytical work in the Sūrya Siddhānta, given the total absence of algebra in Greece during that period. But he would have certainly stumbled upon the use of epicycles and eccentric circles, and even by that measure, severely hobbled as he was due to his ignorance of Trigonometric functions; his models were a step forward in understanding because of their heavy reliance on geometry. We discuss the main differences between the Indic approach and the Greek approach in the previous chapter which is a comparative study of different traditions of astronomy.

IT IS TRUE THAT BOTH THE GREEKS AND THE INDICS USED EPICYCLES (AND ECCENTRICS) BUT THE SIMILARITY STOPS RIGHT THERE.

The Indic never uses a term equivalent to the Equant to arrive at the true longitudes and other parameters The Indic approach as we have already stated was fundamentally analytic and did not make use of geometric constructions. There is a difference between the manner in which the Islamic mathematicians adopted the method of the Syntaxis and what happened in India after the advent of the Syntaxis assuming for the moment the highly unlikely event that the work eventually wound its way to the subcontinent in the 3rd or 4th century of the common era.

We repeat that no mechanism or document has been put forward by the votaries of "Greece "über alles" to show how the Greek knowledge was transmitted to India. This is the same technology that was

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Ptolemy described. Distrust of Ptolemy's observations goes back at least as far as doubts raised in the 16th century by Tyco Brahe and in the 18th Century by Delambre. But Newton's charge of a conscious falsification went beyond that and was quite controversial at the time. Newton was also known for his work on change of the rotation rate of the earth, and historical observations of eclipses.
[228] GIngerich, O, Ptolemy Revisited , QJRAS, vol.22,pp.40-44, 1981,

not available at the First Council of Nicaea[229] to solve the problem of the wandering date of Easter. Ptolemy clearly states that the length of the year is 1/300 of a Nychthemeron less than 365 ¼. They clearly did not have this information or did not understand the significance of it, even though Hipparchus was originally from Bythnea which is in the same region as Nicaea where the council took place. And yet we are expected to swallow the inference that this technology including the complex assumptions behind the epicyclic/eccentric constructions, despite the barriers of distance and language, traveled several thousand miles 2000 years ago, when it could not travel a few miles from Bythnea to Nicaea during a much shorter time.

We see no evidence of the assumptions that Ptolemy made, in the Indic contribution. One sure sign of plagiarism is the propensity to commit the same errors that were in the original and the issue of epistemelogical continuity. There is incomplete understanding of the paradigm. We see no such evidence. In fact the errors that were made by Ptolemy (Chapter VIII), were made only by him.

The **First Council of Nicaea[230]** was a council of Christian bishops convened in Nicaea in Bithynia (present-day Iznik in Turkey) by the Roman Emperor Constantine I in CE 325). If Ptolemy's results were so much more accurate than those of Indic astronomers, why were they not able to fix the Julian calendar. The obvious answer is that Ptolemy's Syntaxis was not available to the Council in 325 CE. There is no evidence that Ptolemy's work was known, leading one to suspect that it may have not existed at that time.

THE CASE OF THE MISSING TABLE OF SINE DIFFERENCES

The occidental history of the trigonometric table is a murky one. This is generally the case when the origin of a subject is not clearly Eurocentric in origin, since the interest of the occidental is considerably modulated when he discovers that the origin of a particular field of endeavor is not Greek. There remains a strong tendency to disregard any literature that has not originated in the occident or at the least to treat it with a vast amount of skepticism. There is usually an attempt to retrieve a measure of priority by using the artifice of 'speculative reconstruction'.

Generally a reference to Trigonometry rarely includes India, unless it is to say that India borrowed the concepts from Greece. The story that is told is that the Arabs used the Greek knowledge from the Elements of Euclid and that they did not add a lot to what the Greeks did. Even if they mention what Āryabhaţa did, it is to state that he borrowed the whole idea from Hipparchus.

We are indebted to Richard Thompson[231] for the following investigation which he has documented in his book. While we have verified his citations and are convinced of the accuracy of his due diligence work, these are the results reported by him. We place on record the pronouncements of the major historians of science.

1. Neugebauer, O."The decisive step in proving that the Indian table of Sines was derived from the Hipparchian Table of chords was made by GJ Toomer[232] "

[229] The First Council of Nicaea was a council of Christian bishops convened in Nicaea in Bithynia (present-day İznik in Turkey) by the Roman Emperor Constantine I in CE 325. The Council was historically significant as the first effort to attain consensus in the church through an assembly representing all of Christendom. This was of great relevance to the evolution of the western Calendar, since one of its accomplishments was the decision to settle the calculation of Easter.

[230] See painting of event under Nicea in Glo-pedia

[231] Richard Thompson "Vedic Cosmography and Astronomy" Motilal Banarsidass Publishers, Delhi,2004

[232] ONHAMA

2. BL Van der Waerden “GJ Toomer has shown that the chord table of Hipparchus, was a table of chords in a circle of radius r = 3,438. Toomer is justified in concluding that Āryabhaţa’s table of Sines was derived from Hipparchus’ table of chords by halving the chords”.[233]
3. David Pingree “This Indian Sine table is closely related to the Hipparchus chord table as reconstructed by Toomer in which ***r*** is also 3438’[234].

Thus all three proclaim that Toomer has proved beyond doubt that Āryabhaţa's Table of R Sines was derived from the Table of Chords of Hipparchus. They certainly give the distinct impression that,

a. there was a table of chords by Hipparchus and

b. that Āryabhaţa not only had access to such a table but also plagiarized it.

On a closer examination of Toomer's paper, we learn that there are no surviving documents containing the Hipparchus Chord Table, not even in a fragmentary form. Toomer[6] himself says," There is no explicit evidence about the nature of the Hipparchus Table". Thus, there is no real proof that such a table ever existed. So much for the famous Hipparchian chord table that nobody has ever seen in the last several centuries. What is astonishing is the certainty with which the Occidental believes that there was **a.** a Sine table despite the absence of a corpus delicti and **b**. that Hipparchus used 3438 as the radius and **c**. and that Hipparchus developed the Sine table

So now we come to the phenomenon of speculative reconstruction. ‘Speculative reconstruction’ is the retrospective manufacturing of evidence by those who consider themselves the inheritors of Greek heritage, to assert that the Greeks did it first. In the case of the Trigonometric table, the occidental usually claims that Hipparchus developed the sine table as exemplified in the quotes above. The evidence for such a claim is very slim indeed and is based on the statement that Ptolemy refers to the work of Hipparchus. But Ptolemy makes no such reference in the Almagest. In fact the only reference that can remotely be considered Trigonometric in character is his use of Chords. But the absence of clearly defined trigonometric functions and his use of the Pythagoras Theorem, would force us to classify him as being unfamiliar with the notion of trigonometric functions in general. If he had defined the Tangent function, there would have been no need for the use of Pythagoras theorem.

The only work of Hipparchus that has survived, namely his catalogue and commentary on stars, gives no account of his mathematical methods. Ptolemy ascribes to Hipparchus two numbers relating to the Moon’s orbit, namely the ratios R/r and R/e, where R, r, and e refer to the radius of the deferent, radius of the epicycle and the Eccentricity of the lunar orbit respectively. Specifically, based on these two numbers, Toomer assumes the existence of a Table of Chords and proceeds to reconstruct this hypothetical table. The chord of an angle is twice the Sin of half of that angle, on a circle of unit radius, i.e.,

$$\mathrm{crd}(\theta)=2\sin(\theta/2).$$

Toomer uses the methods taken directly from the work of Āryabhaţa .

Āryabhaţa uses a circle of radius 3438 units and uses angles at intervals of 3° 45' in his table of R Sines.

Toomer creates a Chord Table in which the Chord lengths are 3438 times the one defined in the above equation, and tabulates them at intervals of 7° 30'. If Toomer had taken directly the values from

[233] *BL Van der Waerden “Geometry and Algebra in Ancient Civilizations” Berlin; Springer Verlag, 1983*
[234] *Pingree, David, “ The recovery of early Greek Astronomy from India “ Journal for the History of Astronomy, vol.vii, 1976, pp. 109-123*

Āryabhaţa's table of R Sines (7.5/2=3° 45'), he would have reconstructed a Table of Chords entirely based on Āryabhaţa. However, Toomer wants to show that there might have existed an independent Table of Chords, so he takes the values of sines from a modern Sine table. To justify his reconstruction, Toomer proceeds to compute the two ratios ascribed to Hipparchus by Ptolemy. Since there is no knowledge of the mathematical methods of Hipparchus, Toomer assumes that Hipparchus might have used the same method as Ptolemy. On the basis of his reconstructed Table of Chords, as described above, and using the method of Ptolemy, Toomer computes the two numbers relating to the Moon's orbit, but gets them wrong. The value for the ratio R/r quoted by Ptolemy and ascribed to Hipparchus, is 3122 ½ / 247½.

The value obtained by Toomer is 2913 / 246 ½ which is not close to the value of Hipparchus. Toomer then argues that Hipparchus must have made a mistake, tries a correction, but gets a value 3082 2/3 / 246 ½ which does not agree either, even after the correction, with that of Hipparchus. But now, Toomer feels that the value is close enough to that of Hipparchus. He concludes therefore, that Hipparchus used a Chord Table of the proposed type and that, in addition, Hipparchus had committed the mistake as proposed by Toomer. Such is the nature of the "conclusive proof" provided by Toomer to show that Āryabhaţa borrowed from Hipparchus. Toomer fares no better in calculating the value of the other ratio, R/e.

TOOMER'S CREATION OF A POST FACTO SINE DIFFERENCE TABLE

The following is a quote from Narahari Achar235 ,who has independently studied the purported, much bandied, but elusive table of Hipparchus "Toomer has constructed the Table of Chords based on a circle of radius of 3438 units of Āryabhaţa and computes the two numbers relating to the Moon 's orbit using the method of Ptolemy. Since the numbers so obtained do not agree with those given by Ptolemy (and ascribed to Hipparchus), the natural conclusion should have been that there is no relationship between the numbers of Hipparchus and those derived from Āryabhaţa . However, in his zeal to prove the non-originality and the indebtedness of Āryabhaţa to Hipparchus, Toomer further hypothesizes a particular mistake *to have been committed by Hipparchus. Even after all this, still there is no agreement between the two sets of numbers. Yet, Toomer offers this as the conclusive proof that Āryabhaţa borrowed from Hipparchus and the other scholars simply acclaim what Toomer says. It may be pointed out that the value of 3438 units for the radius of the base circle common in Indian astronomical texts has been grudgingly acknowledged[9] to be "presumably a development within Indian astronomy independent of Greek influence." Thus, there is no valid basis for the assertion that Āryabhaţa derived his Table of RSines from a Table of Chords of Hipparchus.*

On the other hand, Hayashi[236] has clearly demonstrated recently the originality of Āryabhaţa's RSines table. Hayashi has reexamined, on the basis of grammatically and mathematically precise interpretation of Nīlakaṇţa, another verse in the second chapter of Āryabhaţīya , verse 2.12, which gives second order differences in RSines. While doing so, Hayashi has observed that six of the entries in the table of RSines of Āryabhaţa in verse 1.12 quoted earlier differ from the correct values by one unit. These differences arise because of rounding off ('ardhadhikena', rounded to the next integer because of its being greater than half) and could not have occurred if Āryabhaţa had simply copied a table.

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[235] Narahari Achar, B.N. "Indian Journal of History of Science, 37.2 (2002) 95-99, Āryabhaţa And The Table Of Rsines, Physics Department, University of Memphis, Memphis TN 38152 USA.

[236] Hayashi, Takao, 1/ Āryabhaţa's Rule and Table of Sine-Differences", Historia Mathematica, 24 (1997) 396-406.

It may further be noted that while the use of R=3438 units for the radius of the base circle is common in Indian astronomy texts, other values are also used. For example, Varãhamihīra uses R=120 units and lists values of RSines at intervals of 3°45' in his Panchasiddhāntika. One might suggest this to have been derived from a Greek chord table with R=60. While it is tempting to do so, the mere use of a sexagesimal base number alone, however, should not be taken as proof of borrowing from the Greek (the earliest Vedic base was 360^d *in a year). "*

In Bressoud's paper he makes the obligatory obeisance to " the Greek Origins of Trigonometry" and credits Hipparchus with the realization that 3438 minutes of radius or 1 radian or 1Trijya as it was known in India is an excellent choice for R . No mathematician west of the Bosphorus wants to give up that high ground[237]. The realization that a length measure can be represented by an angular measure and that such an insight was made by an ancient Indian is in essence like giving up the store and I have yet to see a single mathematician, not make this statement, that Hipparchus was the one who did this before the Indians. Bressoud makes the completely gratuitous statement that "there is some evidence that Hipparchus , whose trigonometric tables no longer survive, also may have used a radius of 3438". The gratuitousness of the statement only comes into play when the significance of the radius is not realized. In the next section he explains AB's table very well when he shows that the second difference is approximately equal to - **Sin nθ** (**Rn**)/225(dimensionally incorrect) or using our notation, the more correct but still rounded form used by Nīlakaṇṭa, where his initial angle is in radians (**θ = 225/3438**), **(δn - δn+1)/Rn** $\cong\sim \theta^2$.

There is also a valiant attempt made to reconstruct the problem of the unequal time periods between the equinoxes and solstices and ascribe the knowledge of the trigonometric functions on the part of Hipparchus by Bressoud, but again the use of speculative reconstruction borders on being unethical, because the hope is that the collective memory forgets that it is speculative in the first place and replaces the assumption that this is a plausible approach that might have been used by Hipparchus with the certitude that he in fact was the author of the sine table . In any event there is great reluctance to admit that there is substantial evidence that the origin of trigonometry lies in the Indian subcontinent.

The only description of the construction of a sine table which is widely mentioned in many of the Siddhāntic texts, (these texts are of an ancient vintage dating back to the BCE) is by Āryabhaţa . There do not exist any such tables in the ancient era either in Greece or Babylon or China. Europe has to wait for 1700 years for Barthelemy Pitiscus[238] (August 24, 1561 – July 2, 1613) for its first book on Trigonometry. *Trigonometria: sive de solutione triangulorum tractatus brevis et perspicuus* (1595, first edition printed in Heidelberg), which introduced the word "trigonometry" to the English and French languages, translations of which had appeared in 1614 and 1619, respectively. It consists of five books on plane and spherical trigonometry. Pitiscus is sometimes credited with inventing the decimal point, the symbol separating integers from decimal fractions, which appears in his trigonometrical tables and

[237] Kim Plofker makes the following observation "It has been debated for several decades whether a trigonometric radius of 3438 may have been used in Hellenistic astronomy, and thence transmitted to the Indian tradition. The evidence for this hypothesis is reconstructed from some ratios of astronomical parameters computed by Hipparchus and cited by Ptolemy in the Almagest." We feel that speculative reconstruction cannot be used to make categorical statement that India borrowed from Greece. If the hypothesis includes a speculative reconstruction, then the inference should be stated clearly as being speculative.

[238] The Occident makes the point that it is not enough that a concept be invented, but that there must be contiguous follow through and continuity amongst the successors to the invention in order for a claim of priority to be made. By that standard, Hipparchus would not obviously qualify as the founder of Trigonometry, since it took 1700 years for a successor to appear.

was subsequently accepted by John Napier in his logarithmic papers (1614 and 1619). Pitiscus edited *Thesaurus mathematic* (1613) in which he improved the trigonometric tables of Georg Joachim Rheticus and also corrected Rheticus' *Magnus Canon doctrinæ triangulorum*. We will recall that the Jesuits had the more accurate trigonometric tables by 1560 CE, presumably the very accurate table constructed by Mādhava in the 13th century, which was accurate up to 9 decimal places.

Part of the problem may lie in the definition of what constitutes Trigonometry. In this context we will not consider the discovery of the exact expression for π as being a discovery of Trigonometry. For the purposes of this paper we will define Trigonometry as the science of numerical computation that allows us to convert angular measures into distance measures and vice versa. Using the angular measure as a synonym for linear measures, an insight that is clearly evident in the work and pronouncements of Āryabhaţa and the choice of 3438 minutes (57.2957 degrees or 1 radian) as the radius is not coincidental.

ĀRYABHAŢA'S Π & THE INGENIOUS SINE TABLE

VALUE OF PI

Āryabhaţa assumes a value of **3.1416** for π which is implicit in the calculations for the sine table, which is correct to 4 significant places.

MAIN FEATURES OF THE TABLE OF SINE DIFFERENCES

Āryabhaţa's approach to the Sine table is a highly original one. Not only does his choice of units indicate a degree of maturity with the subject, but it is of a quality that even a 21st century PhD candidate would be proud to say that he developed it. The first major intellectual leap that he made was his choice of unit's .The notion that a linear measure could be expressed as an angle, is an innovation that permits a lot of flexibility and easy deductions that are not immediately apparent in the use of half chords, that the Alexandrian astronomers used. So also is his use of a recursive formula. There is an elegance and beauty in this algorithm, which uses second order differences that simply takes ones breath away.
Let **r** = radius of the circle having the circumference = 21,600 minutes
r = 21,600/2 π = 10,800/ π = 3437.75 kala or minutes = 60 *(r in degrees)
1 radian = 57.2957 ^{o} = 180/ π degrees = 1 Trijya. In order to read the numbers in degrees , divide by 60, and in order to get the modern value of Sine divide the value in the table by 60 π (3438 minutes)
$\mathbf{R_n}$= the Nth Value of the Sine in the Table

$\mathbf{\delta_n}$ = The Nth Value of the Sine Difference = $\mathbf{R_{n+1} - R_n}$

r is the measure in angular units , of the radius of a circle with circumference equal to 21,600 minutes or 360^{o} and is also the measure of the arc of a circle subtended by 1 radian (Trijya) or 57.2957^{o}

$$R_N = R_{N-1} + \Delta_N$$
$$\Delta_N = \Delta_{N-1} - (R_{N-1} / R_1)(\Delta_1 - \Delta_2)$$

EQN SD1 THE RECURSIVE ALGORITHM THAT WAS USED BY ĀRYABHAŢA

prathamāccāpajyārdhādyairūnaM khańditaM dvitiyārdham |
tatprathamajyārdhāŝaistai stairūnāni ŝoṣāńi ||
|| 12 ||
प्रथमाच्चापज्यार्धाद्यैरूनं खञिडतं द्वितियार्धम् ।
तत्प्रथमज्यार्धाशैस्तै स्तै रूनानि शोषाञि ।।

Hayashi's translation -When the second half-chord partitioned (R_2 or Rsine) is less than the first half-chord (R_1), which is approximately equal to the corresponding arc (α), by a certain amount, the remaining RSines-differences are less than the previous ones each by that amount of that (i.e., the corresponding half-chord, R_n) divided by the first half-chord R_1. (AB 2.12).
Another translation - The Rsine of the first arc divided by itself and diminished, gives the second RSines difference. That same first Rsine, when it divides successive Sines, gives the remaining RSine differences.
Note that the second difference is proportional to the negative of the functon which is analogous to the second derivative being proportional to the negatve of the function , the solution for such a differenial equation is the Sine function or exp (ix)t

RATIONALIZATION OF RECURSIVE RELATION

The rationale of the recursive relation is given in the Appendix O on Selected Topics The Ancient Indic was not limited to expressing the length of a linear segment by a linear measure. He was equally comfortable expressing curvilinear distances as an angular measure. Thus R (the length of the arc as well as the radius) can be equally well expressed as an angular distance of 1 radian as its traditional measure which uses units of linear measure.
1 radian, 57.2957^o or as 3438'

R = 10800/3.1416 = 3437.7387 , θ = 225'= 3^o 45'=180/48 degrees = π/48 radians , n = 1,2.3 …24

TABLE 1 ĀRYABHAṬA'S TABLE OF SINE DIFFERENCES						
Actual value of R_n = R sin nθ, minutes	Actual value **R/ R_{24}**,Radians or Trijya	Actual Sine diff **$\delta_{n+1} = R_{n+1} - R_n$**	Āryabhaṭa 's Sine diff, rounded to the minute	Āryabhaṭa sine value	Govindaswami's fractional parts	Āryabhaṭa 's sine diff improved by Govindaswami
224; 50, 19, 56	.0654	224; 50	225	225	-9,37	224; 50, 23
448; 42, 53, 48	.13053	223; 52	224	449	-7,30	223; 52, 30
670; 40, 10,24	.19509	221; 57	222	671	-2,42	221; 57, 18
889; 45, 8, 6	.25882	219; 4	219	890	+ 4,57	219; 4,57
1105; 1, 29, 37	.32144	215; 16	215	1105	+16,22	215; 16, 22
1315; 33, 56, 21	.38268	210; 32	210	1315	+32,26	210; 32, 26
1520; 28, 22, 38	.44228	204; 54	205	1520	-5,34,	204; 54, 26
1718; 52, 9,42	.5	198; 23	199	1719	-36,12	198; 23,48

1909; 54, 19, 5	.55558	191; 2	191	1910	+ 2,09	191;2,09
2092; 45, 45, 51	.60876	182; 51	183	2093	-8.33	182;51, 27
2266; 39, 31, 6	.65934	173; 53	174	2266	-7,02	173; 52, 58
2430; 50, 54, 6	.70711	164; 11	164	2430	+12,10	164; 12, 10
2584; 37, 43, 44	.75184	153; 46	154	2584	-13,11	153; 46, 49
2727; 20, 29, 23	.79335	142; 42	143	2727	-17,14	142; 42, 46
2858; 22, 31, 0	.83147	131; 2	131	2858	+ 2,02	131; 2,02
2977; 10, 8, 37	.86603	118; 47	119	2977	-12,22	118; 47, 38
3083; 12, 50, 56	.89688	106; 2	106	3083	+ 2.42	106; 2,42
3176; 3,23, 11	.92388	92; 50	93	3176	-9,28	92; 50, 32
3255;17,54,8	.94693	79; 14	79	3255	+14,31	79; 14,31
3320; 36, 2, 12	.96593	65; 18	65	3320	+18.08	65; 18,08
3371; 41, 0,43	.98079	51; 4	51	3371	+ 4,59	51; 4, 59
3408; 19, 42, 12	.99144	36; 38	37	3408	-21,19	36; 38,41
3430; 22, 41, 43	.99785	22; 2	22	3430	+ 3,00	22; 3,00
3437; 44, 19, 23	1.00000	7; 21	7	3437	+21,37	7;21,37

THE CASE OF HIPPARCHUS - DID HIPPARCHUS INVENT TRIGONOMETRY?

The name Trigonometry was coined by Bartholomew Pitiscus,[239] and was the title of the book he published, in 1595 *Trigonometria* (literally, the measuring of triangles).

Most western texts on the History of Mathematics credit Hipparchus with the invention of trigonometry. But there is no direct evidence of his work, since there is no extant proof or document indicating that he developed the sine Table and certainly no evidence that he used that is now attributed to Āryabhaţa. In the history of Mathematics[240], Smith remarks that while Plane trigonometry had taken only rudimentary form, Hipparchus worked out a table of chords, and on these grounds, he credits the Greeks with the definitive start of Trigonometry. This is entirely a fanciful extrapolation with almost no evidence to support such a stance.

From all accounts (Smith, Rouse Ball, Heath) Hipparchus was first and foremost an Observational Astronomer but did not have the mathematical skills to do other than the most elementary calculations, and did not match the mathematical skills of Apollonius of Perga who may have been his contemporary. That his work on the stars and constellations, is the first systematic account to understand the motions of the celestial bodies is merely a reflection of the fact that it is unnecessary to embellish the work of Great intellectual savants. The unvarnished truth of their accomplishments is impressive enough. Hipparchus hailed from Asia Minor, as did most of the mathematicians in Asia Minor, and they may have benefited from their relative proximity to the Ancient Oriental schools of Astronomy of which India was the most important contributor, and Jundishapur was the westernmost outpost that we are aware of.

[239] The etymology of Trigonometry includes Trikonamati
[240] Smith, DS , The History of Mathematics, Dover Publications, 1958

We have cited the case of the speculative reconstruction of Hipparchus' putative sine table as an example of how the occidental has tried desperately to claim that the origins of the Sine Table go back to Hipparchus. This is only one example of such conduct.



FIGURE 2 HIPPARCHUS

A typical paean to Hipparchus runs as follows: Hipparchus before-mentioned, who can never be sufficiently praised, no one having done more to prove that man is related to the stars and that our souls are a part of heaven, detected a new star that came into existence during his lifetime; the movement of this star in its line of radiance led him to wonder whether this was a frequent occurrence, whether the stars that we think to be fixed are also in motion; and consequently he did a bold thing, that would be reprehensible even for God - he dared to schedule the stars for posterity, and tick off the heavenly bodies by name in a list, devising machinery by means of which to indicate their several positions and magnitudes, in order that from that time onward it might be possible easily to discern not only whether stars perish and are born, but whether some are in transit and in motion, and also whether they increase and decrease in magnitude - thus bequeathing the heavens as a legacy to all mankind, supposing anybody had been found to claim that Hipparchus of Rhodes (called also Hipparchus of Nicaea or Hipparchus of Bithynia) (c. 190 – 120 BCE) is one of the greatest astronomers of all times. He was born in Nicaea in Bithynia (currently in Turkey) and he made astronomical observations in Nicaea, Rhodes and in Alexandria.

Ptolemy produced with the Almagest the most important book of astronomy for around 1500 years but for this work the contribution of the earlier work of Hipparchus was very important. Almost none of Hipparchus books survived except a commentary on Phenomena of Eudoxus and Aratus of Soli. We know the work of Hipparchus from Ptolemy's Syntaxis and from comments of others." This statement needs to be carefully analyzed for the extent of its veracity.

We are in concurrence that Hipparchus was a keen observational astronomer and drew many insightful inferences, but at the same time we see no evidence that he demonstrated any competence in computational astronomy.

According to Toomer, Hipparchus founded trigonometry, by computing the first trigonometric function, namely, a chord table. However, Toomer is careful to explain that there was no ancient term for trigonometry, 'since it was not counted as a branch of mathematics' in antiquity. Rather, trigonometry was ancillary to astronomy. (There are various ancient classifications of mathematics. For example, the four 'Pythagorean sisters' included arithmetic, geometry, harmonics, and astronomy. Plato, in the Republic Book 7, also discussed the study of stereometry as part of the mathematical curriculum necessary for philosopher-kings.) .

The Hagiography surrounding the name of Hipparchus includes the following passage.

He made an early contribution to trigonometry producing a table of chords, an early example of a trigonometric table; indeed some historians go so far as to say that trigonometry was invented by him.

RESPONSE (4)

We have described the attempts made by Toomer to ascribe the methodology of the missing table of chords, using the highly dubious method of speculative reconstruction, even assuming it were true that

such a speculative reconstruction was successful which it most certainly was not, speculative reconstruction merely establishes that it was possible for Hipparchus to have computed such a table, but it certainly does not establish that he did it given the absence of any extant document authored by him. There is also the well-known fact that the Greeks like the Romans who succeeded them did not know how to do fractional arithmetic or algebra, subjects which wended their way into Europe only in the 16th century. There is a quote in Almagest where Ptolemy is reported to have stated that he had difficulty with fractions. And then he says "In general we will use the sexagesimal system, because of the difficulty with fractions, and we shall follow out the multiplications and divisions"[241] . This reminds us of Marie Antoinette's admonition to the French citizens, "to eat cake if they don't have bread". How is Ptolemy going to deal with sexagesimals, if he has difficulty with fractions. It is quite clear that neither Hipparchus nor Ptolemy had the facility to do the algebra demanded in the Almagest

> *"Even if he did not invent it, Hipparchus is the first person whose systematic use of trigonometry we have documentary evidence***. "** - It is not obvious to us that Hipparchus made systematic use of trigonometry.

RESPONSE (5)

> *If this is so, Hipparchus was not only the founder of trigonometry but also the man who transformed Greek astronomy from a purely theoretical into a practical predictive science.*

Response – In another context Kim Plofker[242] makes the following assertion with respect to the possibility that the calculus had its beginnings in India "*To speak of the Indian "discovery of the principle of the differential calculus" somewhat obscures the fact that Indian techniques for expressing changes in the Sine by means of the Cosine or vice versa, as in the examples we have seen, remained within that specific trigonometric context. The differential "principle" was not generalized to arbitrary functions—in fact, the explicit notion of an arbitrary function, not to mention that of its derivative or an algorithm for taking the derivative, is irrelevant here*"

If she is right that the Indians did not make the necessary generalizations, to initiate the beginnings of analysis, she would be justified in expressing skepticism about the Indian claim to priority in Calculus. But if we apply the same criteria to Hipparchus and his chord table then surely the same remark applies even in greater measure to Hipparchus, who made no pretense of defining new functions, whose properties would bypass the clumsy algebra of Pythagoras' theorem. Merely producing a table of half chords was tantamount to creating multiplication tables, which were ubiquitous in Mesopotamia since most people had very poor skills in manipulating numbers. Creating Tables is not an effective method of broadcasting ones prowess in a subject and certainly one instance of an inverse square law was sufficient to overturn the thousands of tables that have been the bane of the astronomer since the beginning of time. Hipparchus showed little sign of having attained these insights. In the case of the half chords, he certainly did not elevate it to the status of a function and there is no documentary evidence regarding the manner in which he actually produced a table, notwithstanding the speculative reconstructions of Toomer and Pingree.

Further, as we have mentioned elsewhere in this book it gets a little tiresome when the Occidental tries to claim priority in every field of study, despite clear evidence to the contrary, simply because the answer does not come out to be Greek or Babylonian. We feel that the history of Trigonometry is a case in point.

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[241] *Ptolemy's Almagest translated by R Catesby Taliaferro, Great Books of the Western World, vol.15, Encyclopedia Britannica, Chicago , 1996., P.14,*

[242] *http://en.wikipedia.org/wiki/Kerala_school_of_astronomy_and_mathematics*

THE CASE OF JEAN DOMINIQUE CASSINI (THE ASTRONOMER FOR LOUIS XIV) AND THE SIAMESE MANUSCRIPT

The determination of longitude at sea is one of those problems which attracted the attention of scholars and Royalty (I use the plural advisedly), so much so that **Louis XIV** (**1638 – 1715**), the same gentleman, who reputedly made the statement 'l'état c'est moi 'who came to believe in his own divinity and was referred to as the Sun King offered a substantial prize for the best paper on determination of longitude at Sea. Louis XIV however was a very shrewd Monarch, who appointed equally shrewd Ministers like **Jean-Baptiste Colbert**. Colbert in turn was responsible for bringing **Gian Domenico Cassini (1625 – 1712),** the Italian astronomer from Genoa to Paris and Cassini eventually became a French citizen[243]. To Cassini goes the credit for making the Academie Royale a reality and placing astronomy on a sound footing in France. Cassini was responsible for many experiments that led to the determination of longitude at sea. But Louis XIV was not the first monarch to offer a prize. The first country to offer a prize was Spain. First Philip II offered a prize in 1567. Soon after Philip III of Spain came to the throne in 1598 he was advised to offer a large prize to *the discoverer of longitude.*
A prize of 6000 ducats plus 2000 ducat's income for life with 1000 ducats expenses was offered. Philip however was rather indifferent to his responsibilities as king and the huge response to his prize offer left him with little enthusiasm for any of the schemes proposed. One scheme which was proposed was from Galileo. He wrote to the Spanish Court in 1616 proposing that the way to measure absolute time, which could be measured at any point on the Earth, was to use the moons of Jupiter. Galileo first observed the moons in 1610 and by 1612 he had tables of their movements which were accurate enough to allow him to predict their positions several months ahead. A long correspondence over a period of 16 years failed to convince Spain of the virtues of the scheme so, when Holland offered a large prize in 1636, finding the latitude was relatively a simple matter, especially at night, of measuring the altitude of the Pole star above the horizon. It could also be found from the altitude of the sun at noon with the aid of a table. The gnomonic formula is derived by Bhaskara I.

Coming back to Cassini, we need to record his role in the discovery of Ancient Indian Astronomy. It was the French Ambassador to Siam (Thailand), M. de la Loubére who brought to Paris, in 1687 a manuscript containing rules for the computation of the longitude of the Sun and the Moon. The interpretation of the manuscript proved to be a difficult task but Cassini was probably impressed sufficiently with the manuscript, that he undertook the difficult task. Cassini communicated the results of his investigations, which were reprinted in **Mémoires de I'Academie royale des sciences (1699)[244].**

The Siamese manuscript, which was subsequently identified as being of Siddhāntic origin opened with rules for the computation of Ahargana or the number of civil days elapsed from the beginning of an era up to the date on which the mean longitude of the Sun (or the Moon) was desired.

From the use of the fraction, $\frac{11}{703}$ as the ratio of omitted lunar days to the total number of lunar days, for the epoch, Cassini calculated the length of the Synodic month as **29.5305832148 or** $\mathbf{29^d\ 12^h\ 44^m\ 2.35^s}$ (703 lunar months equals $20{,}760^d$). He established the equivalence of 228 solar months (19 years *30)with 235 lunar months (see chapter 4, Table 9 Vedāṇga Jyotiṣa calendar, 19*12+7), Implying the Metonic cycle was known to those who were compiling the rules in the associated Siddhānta. From another calculation related to the manuscript, he came up with 800 revolutions of the sun in 292207 days, giving a sidereal year of length = $\mathbf{365^d\ 6^h\ 12^m\ 36^s}$

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[243] *He changed his name to Jean Dominique Cassini on becoming a French citizen*
[244] *Le, Gentil, Mémoires de l'Académie Royale des Sciences, 8, 279-362,1699*

Clearly Cassini would not have bothered with the document if he thought it was worthless. It was people like Cassini in France and Flamsteed in the UK that allowed Europe to overtake India, starting in the 17th century. But this does not mean that, Europe was the center of all astronomic activity for all time. This episode illustrates the notion that Eurocentricity that is so pervasive today was not as prevalent then in the 17th century in spite of centuries of brainwashing by the Church. I recount this incident and the role that Cassini played in the history of astronomy for two reasons. Cassini himself never tried to hide what he learned from the Indics and never underplayed his debt to the astronomy of the Siddhāntic texts. The second reason is that while most modern astronomy texts give Cassini his due, they conveniently omit his Siddhāntic connection. The lesson here is that one should take what is written about the founders of astronomy, especially in text books written in the west during the twentieth century with a great deal of skepticism. When it comes to history there appears to be selective amnesia, when they do not even mention the incidence of published works but are equally adamant that the Indics plagiarized the work of Ptolemy, Hipparchus, and from a mysterious Pre Ptolemaic source. So, the only instance that they recognize the Siddhāntic astronomy is when it is regarded as Proxy for an earlier mysterious era during which we neither have names nor do we have any records. All this dependence on Indian texts, we would think might engender some respect for the mathematical prowess of the ancient Indic coupled with his ability to maintain records over such long periods of time, but alas all we hear is, that the Ancient Indian has no sense of history, offers no proof, does not realize the value of his own discoveries and that they borrowed everything from Greece. (See Prologue)

THE CASE OF THE DETERMINATION OF LONGITUDE AT SEA - TIME EQUALS LONGITUDE

Since the Earth rotates at a steady rate of 360° per day, or 15° per hour (in **sidereal** time), there is a direct relationship between time and longitude. If the navigator knew the time at a fixed reference point when some event occurred at the ship's location, the difference between the reference time and the apparent local time would give the ship's position relative to the fixed location. Finding apparent local time is relatively easy. The problem, ultimately, was how to determine the time at a distant reference point while on a ship. Several approaches have been tried for determining longitude at sea and these have been described in great detail by C K Raju[245]. Suffice it to say that the Indics had mastered the technology for determining Longitude at sea long before Louis XIV decided to issue a prize for determining the same. The point is that the Occidental takes the position that unless something is discovered in Europe it doesn't exist.

THE CASE OF THE EQUANT

There is a fundamental difference between the Greek and Indic models when it comes to the use of the Equant. The Equant, if we adopt Ptolemy's definition, is the point on the major axis of the apsidal line about which the planet rotates uniformly. It is usually offset from the geometric center, the same distance as the earth, by an amount that is monotonically increasing with the degree of ellipticity of the orbit. Equant (or Punctum aequans) is a mathematical concept developed by Claudius Ptolemy in the 2nd century CE to account for the observed motion of heavenly bodies.

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[245] Raju, Chandra Kant CFM, Chapter 4, p.225

The equant point, indicated in the diagram by the point C, is placed so that it is directly opposite the Earth from the center of the deferent, indicated by the 'x'. A planet or the center of an epicycle (a smaller circle carrying the planet) was conceived to move with a uniform speed with respect to the equant. In other words, to a hypothetical observer placed at the equant point, the center of the epicycle would appear to move at a steady speed. However, the planet/center of epicycle will not move uniformly on its deferent. This concept solved the problem of accounting for the anomalistic motion of the planets but was believed by some to compromise the goals of the ancient astronomer, namely uniform circular motion. Noted critics of the equant include the Persian astronomer Nasir al-Din Tūsi, who developed the Tūsi-couple as an alternative explanation, and Nicolaus Copernicus. Dislike of the equant was a major motivation for Copernicus to construct his heliocentric system.
For some obscure reason, the equant is interjected into Ancient Indic Astronomy by those who should have known better[246]. The Equant is never mentioned in ancient Indic Astronomy. There is no reason for the Indic to do so, since, the Indic never made the assumption of a uniform angular velocity for the planets and their orbits. Furthermore he had no need to make such an assumption (of a uniform angular velocity) and hence had no need for an Equant. It is the benign neglect of the uniform angular velocity postulate (I presume) that has prompted the dismissal of the Indic models by ON and Pingree as being crude. But there is no need for any model to be more complex than it needs to be. The primary problem with Ptolemy's models has been explained in the section on Ptolemy's errors. The only condition under which he was able to get satisfactory results was for those planets with low Eccentricity. In hindsight this should hardly come as a big surprise to anybody and if we include sufficient terms of higher degree in ***e***, the Ptolemaic model should approach the Keplerian model. But alas, the Greeks had no such skills.

I have been informed that it is no longer being asserted that Toomer's attempt at recreating the Sine Table of Hipparchus is the clinching argument for the thesis that India acquired the Trigonometry from the Greeks. In fact Van Brummelen sent me the following response when I challenged him on this viewpoint;

"However, the case for transmission was revived, I think strongly, by a paper by Dennis Duke (2005). It is this paper to which you probably want to respond, rather than Toomer. On the matter of the origin of the subject, I do tend to side with transmission, although I provide references to opinions on the other side of the issue. On this, I think we may have to agree to disagree."

Of course when the word transmission appears it is implicit that the only transmission that is entertained is the one from Greece to India. So, we examined Dennis Duke's paper to see whether it deserves the right to be called the defender of the transmission thesis. Needless to say I found his logic faulty, although it is novel in its approach. He is obviously not familiar with the bulk of the Indian literature when he makes the assertion that "*The fact that no Indian text gives the slightest hint regarding the origins of their models or the empirical basis of their model parameters is not helpful,*" but then he goes on to soften the blow by adding '*but except for the Almagest, the same is largely true of ancient western astronomical texts*'. To which we may add that the vaunted adherence to uncorrupted data in the Almagest for which the Occidental takes great pride has been seriously called into question by RR Newton. In fact there are plenty of commentaries (the Āryabhaţīya alone has over 14 commentaries spread out over a thousand years) it is the commentaries that one should go to for pedagogical treatment of the subject. In the next section on Proof we list a lot of the original sources that contain Upapatti's or Rationalizations of the original works. One misconception that the Occidental has labored under is the notion that everything worthwhile was seeded by a small group of Aryans (never mind that they were savage and rustic when they arrived) who transformed themselves into the

[246] *Duke, D.,2005*

intellectual elite of India and when their racial and genetic strain died out, so did the mathematical tradition. To bolster such an idea they would name the 3 or 4 top mathematicians in the early centuries, and neglect to mention that there were at least 200 mathematicians of world class caliber that studded the Indian scene over the 2000 years since the first Siddhāntas appeared. So the statement that Duke makes is most likely a result of ignorance of where to look. But this would not be the first time in History that an otherwise rational scholar would insist that if he was not aware of a certain piece of work, it did not exist.

In most instances when the Occidental seeks to devalue the contributions of the 'other' he will invoke the opinion (rather than the unattested 'fact') that the accuracy of the Indic results suffer from inferiority when compare to the Greek data. But Duke takes the view that the agreement between the Indic results of the mean and the anomaly and the corresponding results from the Almagest is proof that the Indians plagiarized from the Greeks. I remain deeply in admiration of the creativity and the extraordinary arguments that the Occidental will marshal to support his thesis that the Greeks should be granted priority in every topic, even when there is not a single document attesting to such a priority.

THE NATURE AND EXTENT OF PROOF IN ANCIENT INDIAN MATHEMATICS AN EXAMPLE OF A HEURISTIC AS WELL AS A RATIONALE (UPAPATTI)

The comment often made in the occident is that there is a general absence of proof in the ancient Indic texts. This reinforces the view that the Indic contributions were borrowed from elsewhere. Typical of such brashness was the remark of Morris Kline[247] , May 1, 1908 – June 10, 1992 Professor Emeritus at Courant institute of Mathematical sciences. '*As our survey indicates the Hindus were interested in and contributed to the arithmetical and computational activities, rather than to the deductive pattern. Their name for mathematics is Gaṇita which means the Science of calculation. There is much good procedure and technical facility but no evidence that they considered Proof at all. They had rules but apparently no logical scruples. Moreover, no general methods or new viewpoints were arrived at in any area of mathematics.*' As if all this was not bad enough, he delivers the final coup de grace.

It is fairly certain that the Hindus did not appreciate the significance of their own contributions. The few good ideas that they had, such as separate symbols for the numbers from1 to 9 ', the conversion from positional notation in base 60 to base 10, negative numbers and the recognition of 0 as a number, were introduced casually with no apparent realization that they were valuable innovations. They were not sensitive to mathematical values. The fine ideas that they themselves advanced, they commingled with the crudest ideas of the Egyptians and Babylonians.

For a person who just finished writing a book, whose title includes the phrase - 'The loss of certainty', his certainty in coming to this conclusion is stunning in its finality. He does not brook of another opinion. He does not seem to realize that the need for a decimal place value system arose in part because it is intimately connected with the recognition that certain numbers are irrational. The chagrin that he felt, because the entire world is using a system of numbers that was so casually devised by the Hindu must be rankling deep and hard in his soul in order for him to make such a patently Eurocentric statement.

The widely held belief in the occident that there are no proofs given in the ancient Indic computational sciences is a highly simplistic view that betrays a lack of understanding of the Indic episteme, and it is certainly based on a false premise. Again we are reminded of Napoleon's dictum that we should

[247] *Kline,Morris, Mathematics, the loss of certainty, OUP, New York, 1980, p.111*

attribute not to malice that which can be explained by sheer incompetence, their insistence on not doing the due diligence with the plethora of Sanskrit texts available, is yet another example of the Parable of the Lost Coin[2]. The topic has been dealt with in great detail by MD Srinivas[248], and C.K. Raju[249] and the reader is referred to these. At the risk of over simplification we will briefly discuss this issue.

The fundamental question here is what constitutes proof. Generally speaking, we consider a proof of a theorem or a principle to be a derivation of a result with a minimum number of restrictions or assumptions and maximum universality of the result. Upapatti's[250] play a major role in the Indic Episteme. What does not constitute Proof under the Indic episteme? As an example we cite the extensive use of *Reductio ad absurdum (*Latin: "reduction to the absurd") in Euclid's elements. This has never been considered an acceptable mode of proof by the Indics

I ask the same question that I ask of the Occidental when he says the Indic historical record does not meet the criteria of historiography; what is the comparable standard of another civilization in 4000 BCE or even in 3000 BCE or 2000 BCE. None that we can think of. Even Egypt and Babylonia usually mentioned in the same breath as India, have major gaps as we have seen. Egypt[251] has always had major problems and uncertainties with its lists of dynasties. Similarly, in analogy with history or using the pramāṇa of Upamāna we ask, "What is the gold standard for comparison of what constitutes an adequate proof, in the context of a mathematical result in 400 CE".

At the outset let me say that it is just not true that no proofs were offered by the ancient Indics. Generally the farther back we go, the use of Sūtra technology in the ancient era was to conserve the length of the text, so as not to put too heavy a burden on the memory of the human being, who carried the responsibility of recalling all he was taught, without ever having to commit it to a written medium.

It was not enough to store the information but it was also essential to retrieve it in short order. Even when writing materials were available, old habits die hard and brevity was usually prized as a talent. But as we get past the initial centuries of the Common Era, we see more and more commentaries and explanations of past works. Some of the best known astronomers of India were also prolific commentators on their predecessors. The Āryabhaṭīya alone has about 14 commentaries. The commentators (Bhāṣya-kāra), usually write a commentary (Bhāṣya) in order to explicate on several nuances that may or may not have been brought out in the original text. They also provide the Upapatti[252] of the major results

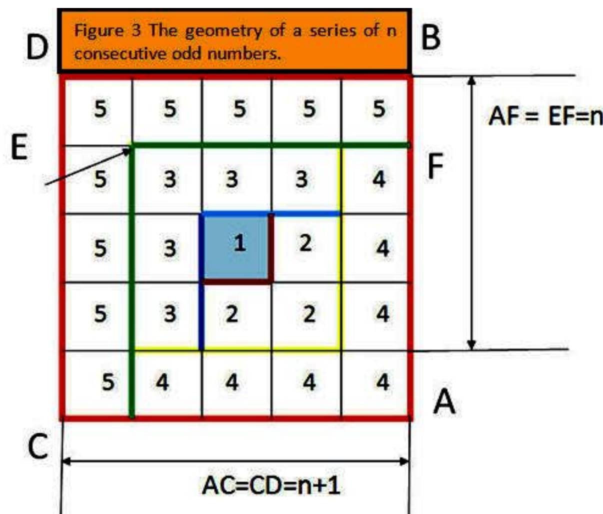


Figure 3 The geometry of a series of n consecutive odd numbers.

[248] *Gerard Emch, R Sridharan, and M D S Book agency, New Delhi, 2003. See also Policy Studies New No.6, old number 29, B*

[249] *Raju, Chandra Kant CFM, Chapter 2, p.5*

[250] *See appendix D, the Vedic episteme, under Epistemology*

[251] *Kitchen, KA, The Chronology of Ancient Egypt, World archaeology, 23, 3, p 201-209*

[252] *Note that Upapatti is an essential ingredient of the ancient Indic episteme (one of the pramānās used to create new knowledge). See Appendix D, for the various Pramānās in the vedic episteme*

obtained in the earlier text. Also it must be remembered that the audience (readership) in the ancient era was smaller than it is today, and they were catering to a small group of professionals, who may not have deemed it necessary to explicate matters. This situation was not unique to India. The total readership of the Latin translation of al Majisti was probably in the order of a few dozen in all of Europe, if that. With the advent of the printing press and a vastly increased readership, the need for brevity disappeared and it is safe to say that every major result in ancient India had an Upapatti's attached to it, sooner rather than later.

A HEURISTIC APPROACH TO THE SUM OF A SERIES OF N ODD NUMBERS

A delightful version of what constituted a proof in ancient India is the result of the summation of a series consisting of odd numbers. This series and its geometrical representation are first mentioned in the Baudhāyana Sulva sutra[253](BSS) . We have to wait till 1225 when Leonardo of Pisa (also known as Fibonacci , mentions this series in the Liber Quadratorum, which many consider to be his best work, rather than the Liber Abaci, which was specifically written to introduce the Hindu DPV system to Europe. However, in the popular books of the west, the fact that this was first proved in the BSS is conveniently omitted.[254]

$\sum 1 + 3 + 5 + \ldots (2n-1) = n^2$, where n is the number of terms in the series
1 = 1, 1+3 = 4, 1+3+5 = 9, 1+3 + 5 + 7 = 16, 1+3+5+7+9 = 25
The number inside the square represents n, the number of terms in the series, and the number of occurrences of each n, represents the nth term in the series(2n+1). This would qualify as an Upapatti's, although the purist may end up looking for conditions under which such a proof would no longer be valid.

Baudhāyana gives a geometrical proof by constructing a series of squares in the following manner; to prove the result, it is sufficient to show that in going from a sum of n terms of odd numbers to n+1 terms of odd numbers we are adding the general expression for the additional squares (each square represents an ordinal number), which is equal to the additional squares we are adding when going from n to n+1 terms. The algebraic expression for the difference in going from 4 terms to 5 terms must equal the additional number squares in going from square
Let $S_n = n^2$ be the sum of n terms,

$(n+1)^2 - n^2 = n^2 + 2n + 1 - n^2 = 2n + 1$. But these are exactly the number of additional squares, in figure 3 in going from n = 4 to n + 1= 5 because side BD + side AF = 2n+ 1 squares = 9. Note that this is the n^{th} term of the series.
Since a picture is worth a thousand Euros we will list below some of the works containing Upapatti's[255]. Please note that this is not an exhaustive listing. This is merely placed here so that the average reader is aware that there are plenty of locations where the proofs or rationales for a particular result can be found. The search for an adequate English translation can be sometime daunting but is no more so than finding the English translation of a Latin original.

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253 Datta, B., The science of the Sulva, A study in early Hindu geometry, University of Calcutta, 1932
254 Wellers, Michael., "Algebra , the x and y of everyday math" Fall river press, New York, ISBN 978-1-4351-1400-5
255 There is a complete list of such books with Upapatti's in M D Srinivas paper Proofs in Indian Mathematics" which is one of the essays in Gordon Emch, R Sridharan and M D Srinivas "Contributions to the History of Indian Mathematics" Hindustan Book agency, New Delhi, 2003. See also Srinivas, M D., The Indian tradition in Science and technology, Center for Policy Studies New No.6, old number 29, Balaiah Avenue, Luz corner, Mylapore, Chennai, 600004

Nr.	TABLE 2 EXAMPLES OF UPAPATTI
	Āryabhaţīyabhāṧya of Nīlakaņţa Somasutvan (ca.1501 CE) on Āryabhaţīya of Āryabhaţa, ed. By K Sambasiva Sastri, Trivandrum, 1931, 1932, 1957
	Gaņita Yukti Bhāṧā by Jyeşţhadeva (ca.1530) Rationales in Mathematical astronomy, translated and edited by KV Sarma, explanatory notes by K Ramasubramanian, MD Srinivas, M S Sriram
	Khandakhādyaka Paddhati by Lallāchārya
	Śiromaņiprakāśa of Ganeśa Daivajna on Siddhānta-Śiromaņi of Bhāskarāchārya, ed. By VP Apte, 2 Volumes, Puńē, 1939, 1941
	Bhāṧya of Bhāskara 1 on Āryabhaţīya of Āryabhaţa , ed. [with the commentary (*bhāşya*) of Bhāskara I and Someshvara] K. S. Śukla, New Delhi: Indian National Science Academy, 1976.
	Bhaskarivabhāsya **by** ***Govindasvāmin*** (c. 830 CE) Billard (1971), p.81 Commentary on the *Āryabhaţīya* by Bhāskara (629 CE) [K. S. Śukla and K. V. Sarma (1976)
	Vāsanabhāsya of Chaturveda Prthudaksvamin
	Vivarana by Bhāskarāchārya on Shishyadhivṛddhida Tantra by Lalla (tenth century CE)
	Vāsana of Bhāskarāchārya on his own Bija Gaņita
	Mitākshara or Vāsana of Bhāskarāchārya on his own Siddhānta- Śiromaņi **(**1) Edited with Bhāskara's commentary. *Vāsana* by Sudhakara Dvivedi, Kashi Sanskrit Series, No. 72, Benaras,
	Gaņitayuktāyah, Tracts on Rationale in Mathematical astronomy by Various Kerala astronomers (16^{th} to 19^{th} century), KV Sarma (ed.) Hoshiarpur
	Grahasphutanayane Vikshepavasana of Nīlakaņţa Somasutvan in Gaņitayuktāyah, Hoshiarpur, 1979 , Sarma, K.V. (ed.),
	Yukti-dīpīka - an extensive commentary in verse on Tantrasamgraha based on Yuktibhāṣā by Sankara Variyar
	Kriya-kramakari - a lengthy prose commentary by Sankara Variyar on Līlāvati of Bhāskara II**.**
	Buddhivilāsini of Ganeśa Daivajna, commentary on Līlāvati

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Comment [4]:

It can be seen from these examples that there is logical rigor which is characteristic of these works in the Indic approach, contrary to what Morris Kline[256] asserts when he says that and I quote *'They had rules but apparently no logical scruples'.*

As a general rule of thumb, commentaries are more likely to have Upapatti's, than the original work. A good example of a proof is Nilakanta's unified treatment of planetary motions which is similar to that of Tycho Brahe and was enunciated 100 years before Tycho.

NILAKANTA'S UNIFIED TREATMENT OF PLANETARY MOTIONS

By this time it is becoming increasingly clear that Nīlakaņţa, who lived for over a hundred years, was a perceptive individual, who had made a significant contribution to the understanding of the world around us. He revised the traditional view of the solar system in very significant ways. It also shows us how agile the Indians were in terms of the heuristics of solving a problem. A heuristic refers to experience-based techniques for problem solving, learning, and discovery. Heuristic methods are used to come to an optimal solution as rapidly as possible. Part of this method is using a "rule of thumb", an educated guess, an intuitive judgment, or common sense. A heuristic is a general way of solving a problem. In more precise terms, heuristics stand for strategies using readily accessible, though loosely applicable, information to control problem solving in human beings and machines.

[256] *Kline, Morris, Mathematics, the loss of certainty, page111, OUP, NY, 1980*

So what was the advance made by Nīlakaṇţa and why is it so significant and why do I consider it to be good example of the heuristic approach that was popularized by George Polya[257]. The following is an excerpt from the original paper by MD Srinivas[258].

"Nilakanta's revision of the traditional computational scheme for the longitudes and latitudes of the interior[259] planets, Mercury (Budh) and Venus (Shukra) was based on his clear understanding of the latitudinal motion of these planets. It is this understanding that led him to a correct understanding of the motion of the planets. The best exposition can be found in the Āryabhaţīyabhāṡya by Nilakanta;

"Now the Āryabhaţiya explains the nature of the orbits and their locations for Mercury and Venus. In this way for Mercury the increase of the latitude occurs only for 22^d and then in the same numbers of days the latitude comes down to zero. Thus Mercury moves on one side of the Apamandala (the plane of the ecliptic) for 44^d and it moves on the other side during the next 44^d. Thus one complete period of the latitudinal motion is completed in 88^d, which happens to be the period of revolution of the Ṡīghroccha (perihelion of Mercury).
The latitudinal motion is said to be due to that of the Ṡīghroccha. How is this appropriate? Isn't the latitudinal motion of a body dependent on the motion of that body only, and not because of the motion of something else? The latitudinal motion of one body cannot be obtained as being due to the motion of another body. Hence we should conclude that] Mercury goes around its own orbit in 88^d. However this also is not appropriate because we see it going around in one year and not in 88^d. True; the period in which Mercury completes one full revolution around the Bhagola (the celestial sphere) is one year only (like the Sun]. In the same way Venus also goes around its orbit in 225^d only."

It is this latitudinal period of 88 days that gave Nilakanta the final clue that the inferior planets (Mercury and Venus) were in fact orbiting the Sun and not the Earth. How so? The clarity of Nilakanta's subsequent explanation is simply stunning in the manner in which he frees himself, not totally but in large measure, from the gulag of the geocentric model.

All this can be explained thus: The orbits of Mercury and Venus do not circumscribe the Earth. The Earth is always outside their orbit. Since their orbit is always confined to one side of the (geocentric] celestial sphere. In completing one revolution they do not go around the twelve RāṠi (the twelve signs). For the inferior planets, the mean Sun is the Ṡīghroccha (converts the heliocentric value of the Manda anomaly to the geocentric value. It is their own revolutions, which are stated to be the revolutions of the Ṡīghroccha. In ancient texts such as the Āryabhaţīya, it is only due to the revolution of the Sun (around the Earth that they i.e. the interior planets. Mercury and Venus) complete their movement around the twelve RāṠi and complete their revolution of the Earth. Just as in the case of the exterior planets (Jupiter etc.). The Ṡīghroccha (i.e. the mean Sun) attracts (and drags around the manda-kaksya-mandala (the Manda orbits on which they move). in the same way as it does for these (interior] planets also.
"To integrate the diagrams for all the planets into a single diagram of the planetary system, we shall have to use the notion of bhu-tāra-graha-vivara or the Earth-planet distance. Nīlakaṇţa has discussed this extensively in his own commentary *Āryabhaţīyabha Ṡya* and has shown how the effects of the

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[257] George Polya "How to solve it'. In my view George Polya's (who was a colleague of Srinivasa Ramanujan at Cambridge) approach is a Paramparic successor to the epistemology of the Veda, and then , it does not surprise me that I thought of the word heuristic when I came across the solution to the planetary problem as visualized by Nilakanta

[258] MD Srinivas 2008, see Primary and other sources in Appendix G

[259] We will use the term interior planet in the rest of the book, rather than the inferior planet used in the west, since there is nothing inherently inferior about Venus and Mercury, other than the fact that they have smaller orbital radii than the rest of the planets.

latitudinal motions of the planets should be taken into account in the computation of the Earth-planet distance. The final picture that we would obtain by putting all planets together in a single diagram adopting a single scale is essentially what Nīlakaṇţa has described as the qualitative picture of planetary motion that we presented earlier: The five planets, Mercury, Venus, Mars, Jupiter, and Saturn move in eccentric orbits around the mean Sun which goes around the Earth. The planetary orbits are tilted with respect to the orbit of the Sun or the ecliptic, and hence cause the motion in latitude. Since it is well known that the basic scale of distances are fairly accurately represented in the Indian astronomical tradition, as the ratios of the radius of the *Ṡighra* epicycle to the radius of the concentric *(trijya)* is very nearly the mean ratio of the Earth-Sun and the Earth-Planet distances (for exterior planets) or the inverse of it (for interior planets), the geometrical picture of planetary motion will also be fairly accurate in terms of the scales of distances. "We shall term this model the Nīlakaṇţa-Tycho Model. The net result is that Nīlakaṇţa ends up with a model very much like that of Tycho Brahe, but one hundred years before Tycho. It is interesting to see what the Jesuits took back from Malabar in 1560 and whether Tycho Brahe did have access to these papers, given that he always had excellent relations with the Vatican.

INDIAN INFLUENCE ON CHINESE ASTRONOMY

Indian astronomy reached China with the expansion of Buddhism during the Later Han dynasty (25–220 CE). Further translation of Indian works on astronomy was completed in China by the Three Kingdoms era (220–265 CE). However, the most detailed incorporation of Indian astronomy occurred only during the Tang Dynasty (618-907 CE) when a number of Chinese scholars—such as Yi Xing— were versed both in Indian and Chinese astronomy. A system of Indian astronomy was recorded in China as Jiuzhi-li (718 CE), the author of which was an Indian by the name of Qutan Xida—a translation of Devanagari Gautama Siddhartha—the director of the Tang dynasty's national astronomical observatory.

I am indebted to Prof Bhu Dev Sharma for bringing the following to my attention. The astronomical table of Sines by the Indian astronomer and mathematician, Āryabhaţa, was translated into the Chinese astronomical and mathematical book of the Treatise on Astrology of the Kaiyuan Era (*Kāiyuán Zhānjīng*), compiled in 718 CE during the Tang Dynasty. The *Kāiyuán Zhānjīng* was compiled by the aforementioned Gautama Siddhartha, an astronomer and astrologer born in Chang'an, and whose family was originally from India. He was also notable for his translation of the Navagraha calendar into Chinese.

Another interesting study has recently been brought out by Nobel Laureate Amartya Sen[260]. In a chapter on 'China and India', he mentions, "Several Indian mathematicians and astronomers held positions in China's scientific establishment, and an Indian scientist, Gautama Siddhartha (Qutan Xida, in Chinese) even became the president of the official Board of Astronomy in China in the eighth century." Sen further writes: "Calendrical studies, in which Indian astronomers located in China in the eighth century, … were particularly involved, made good use of the progress of trigonometry that had already occurred in India by then going much beyond the purported) Greek roots of Indian trigonometry. The movement east of Indian trigonometry to China was part of a global exchange of ideas that also went west around that time. Indeed this was also about the time when Indian trigonometry was having a major impact on the Arab world (with widely used Arabic translations of the works of Āryabhaṭa, Varāhamihīra, Brahmagupta and others) which would later influence European mathematics as well, through the Arabs."

[260] *Sen, Amartya, The Argumentative Indian, 2005*

Sen points out, "Gautama Siddhartha (Qutan Xida) produced the great Chinese compendium of astronomy *Kāiyuán Zhānjīng* – an eighth-century scientific classic. He was also engaged in adopting a number of Indian astronomical works into Chinese. For example, *Jiuzhi li*, which draws on a particular planetary calendar in India ('Navagraha calendar) is clearly based on the classical Pancha Siddhantica by VarāhaMihīra."

CONCLUSIONS ON THE DIRECTION OF TRANSMISSION

There is not much left to say. The entire edifice that the Occident has built up using the prop of Greek heritage in Mathematics and Astronomy needs to be re-examined for its veracity. It is important that any assumptions or hypotheses implicitly made are explicitly stated. Most importantly, it is simply unacceptable that the Occidental alter the history of nations merely to satisfy his need to be recognized as a civilization with a competitive antiquity. While final conclusions await further study, it is reasonable to conclude that;

1.There was no transmission of Trigonometric functions from either Greece or Babylon to India Both the Jaina as well as the Siddhāntic savants made use of Trigonometric functions well before Hipparchus. The obverse transmission becomes a moot issue since Greece was no longer in the picture as a front runner, after Ptolemy, and eventually the Occident learnt their Trigonometry from the Indians via the Arabs who undoubtedly expanded the range of the subject immensely because of their interest in Geodesy and Astronomy necessitated by their need to face Mecca at specific times during the day. The etymology of the sine function is a clear cut indication of the path that trigonometry took till the time of Bartolommeo Pitiscus, Peuerbach and Regiomontanus.

There is no shame in admitting that the Occident did not have priority in inventing Trigonometry, since the Occident eventually overtook the Indics by not relying solely on a Kinematic Model but one that addresses the Physics of the problem and in the nineteenth Century Europe steadily pulled ahead of India both in Astronomy and Mathematics, so that by the end of the nineteenth century India was at least a hundred years behind The Occident. That the colonized populace of India had far greater problems of survival, than those of Mathematics and Astronomy, does not mitigate the reality of the situation that the Occident made massive progress on all fronts. But our contention is that it was not always thus, at least not until 1750 CE. There is however more than a little hubris in trying to prove that Hipparchus 'DID IT' on such slender and inconclusive evidence. It is possible that the silence of the Indic has emboldened the Occident to make ever more extravagant claims

2. On the subject of mean motions of the Sun and the planets, surely the antiquity of the Indics can hardly be disputed. With the use of the Ahargana, they had reduced the problem to an arithmetical problem albeit one involving large number or digits (which was mainly a matter of staying to the left of the decimal point). Apparently, the practice of using large numbers predates the use of numbers with the numbers to the right of the decimal point, representing, fractions with denominators ordered in increasing powers of ten. This became again in time a moot issue, once the entire decimal concept was married to the place value system.

3. As far as the use of Epicycles and Eccenters is concerned again the chronology does not support a transmission to India from Greece but it is difficult to say with any degree of certainty whether there was or was not any transmission in either direction and we prefer to remain agnostic on this aspect, while we lean to the Indics primarily because of their longer antiquity and the uniqueness and distinctiveness of their approach.

4. We have listed Ptolemy's errors not in a pejorative sense but to do a comparative study of the Indic and Ptolemaic approaches. As far as we can discern, among the six errors that we have listed as Ptolemy's errors, only one shows up in the Indic column, which weakens the case in favor of plagiarization in either direction. Our preference remains in favor of independent developments, notwithstanding the tortuous logic of current day revisionist Historians who try to equate plausibility with certitude, using speculative reconstruction. I include Duke, Toomer, and Pingree in this category.

5. The only remark of an ontological character, we can make in this regard is that the Indic civilization is unique in that it remains the sole survivor of the galaxy of great civilizations that studded the planet over the last several millennia. The Indic civilization had great staying power in the past. Whether such a status can be maintained in the future, is entirely dependent on the Indic and whether he can synthesize the new knowledge efficiently as I mentioned in the Preface.

CHAPTER X
A GLOBAL PERSPECTIVE ON CALENDARS

THE EGYPTIAN CALENDAR

The ancient civil Egyptian calendar had a year that was 360^d long and was divided into 12 months of 30^d each, plus 5 extra days (epagomenes, Greek ἐπαγόμεναι) at the end of the year. The months were divided into 3 "weeks" of ten days each; an arrangement remarkably similar to the French Republican Calendar invented nearly 5,000 years later. Because the ancient Egyptian year was almost a quarter of a day shorter than the Solar year and stellar events "wandered" through the calendar, it is referred to as *Annus Vagus* or "Wandering Year".

A tablet from the reign of First Dynasty King Djer (c. 3000 BC) was conjectured by early Egyptologists to indicate that the Egyptians had already established a link between the heliacal rising of Sirius (Egyptian *Sopdet*, Greek *Sothis*), and the beginning of the year. However, more recent analysis of the pictorial scene on this tablet has questioned whether it actually refers to Sothis at all. Current knowledge of this period remains a matter more of speculation than of established fact.

The Egyptians may have used a Lunar calendar at an earlier date, but when they discovered the discrepancy between the Lunar calendar and the actual passage of time, they probably switched to a calendar based on the Nile inundation. The first inundation according to the calendar was observed in Egypt's first capital, Memphis, at the same time as the heliacal rising of Sirius. The Egyptian year was divided into the three seasons of *akhet* (Inundation), *peret* (Growth - winter) and *shemu* (Harvest - summer).

The heliacal rising of Sothis returned to the same point in the calendar every 1460 years (a period called the *Sothic cycle*). The difference between a seasonal year and a civil year was therefore 365^d in 1460^y, or 1 day in 4 years. Similarly, the Egyptians were aware that 309 lunations nearly equaled 9125^d synodic period of

$\frac{9125}{309}$ = **29.5307443366^d**; recall the value in the Sūrya Siddhānta was **29.530587946^d)** , or 25 Egyptian years, which was likely used in the construction of the secondary Lunar calendar. For much of Egyptian history, the months were not referred to by individual names, but were rather numbered within the three seasons. As early as the Middle Kingdom, however, each month had its own name. These finally evolved into the New Kingdom months, which in turn gave rise to the Hellenized names that were used for chronology by Ptolemy in his Syntaxis, and by others.

The precise orientation of the Egyptian pyramids affords a lasting demonstration of the high degree of technical skill in watching the heavens attained in the 3rd millennium BC. It has been shown the Pyramids were aligned towards the pole star, which, because of the precession of the equinoxes, was at that time Thuban, a faint star in the constellation of Draco. Evaluation of the site of the temple of Amun-Re at Karnak, taking into account the change over time of the obliquity of the ecliptic, has shown that the Great Temple was aligned on the rising of the midwinter sun. The length of the corridor down which sunlight would travel would have limited illumination at other times of the year.

Astronomy played a considerable part in religious matters for fixing the dates of festivals and determining the hours of the night. The titles of several temple books are preserved recording the movements and phases of the sun, moon, and stars. The rising of Sirius (Egyptian: Sopdet, Greek: Sothis) at the beginning of the inundation was a particularly important point to fix in the yearly calendar. From the tables of stars on the ceiling of the tombs of Rameses VI and Rameses IX it seems that for fixing the hours of the night a man seated on the ground faced the Astrologer in such a position that the line of observation of the pole star passed over the middle of his head. On the different days of the year each hour was determined by a fixed star culminating or nearly culminating in it, and the position of these stars at the time is given in the tables as in the centre, on the left eye, on the right shoulder, etc. According to the texts, in founding or rebuilding temples the north axis was determined by the same apparatus, and we may conclude that it was the usual one for astronomical observations. In careful hands it might give results of a high degree of accuracy.

PTOLEMY AND THE ROMAN EMPIRE

According to Roman writer Censorinus, the Egyptian New Year's Day fell on July 20 in the Julian Calendar in 139 AD, which was a heliacal rising of Sirius in Egypt. From this it is possible to calculate that the previous occasion on which this occurred was 1322 BC, and the one before that was 2782 BC. This latter date has been postulated as the time when the calendar was invented, but Djer's reign preceded that date. Other historian’s push it back another whole cycle, to 4242 BC.

In 238 BC, the Ptolemaic rulers decreed that every fourth year should be 366^{d} long rather than 365. The Egyptians, most of whom were farmers, did not accept the reform, as it was the agricultural seasons that made up their year. The reform eventually went into effect with the introduction of the "Alexandrian calendar" by Augustus in 26/25 BC, which included a sixth epagomenal day for the first time in 22 BCE. This almost stopped the movement of the first day of the year, 1 Thoth, relative to the seasons, leaving it on 29 August in the Julian calendar except in the year before a Julian leap year, when a sixth epagomenal day occurred on 29 August, shifting 1 Thoth to 30 August.

Reformed calendar – The reformed Egyptian calendar continues to be used in Egypt as the Coptic calendar of the Egyptian Church and by the Egyptian populace at large, particularly the *fellahin* to calculate the agricultural seasons. Contemporary Egyptian farmers, like their ancient predecessors, divide the year into three seasons, namely winter, summer, and inundation. It is also associated with local festivals such as the annual Flooding of the Nile and the ancient spring festival *sham en nisim*.

The Ethiopian calendar is based on this calendar but uses Amharic names for its months and

TABLE 1 EGYPTIAN MONTHS		
AKHET (flood)	PERET (germination)	SHEMOU (collect)
Thot from 07/19 to 08/17	Tiby from 11/16 to 12/15	Pachons from 03/16 to 04/14
Paophi from 08/18 to 09/16	Méchir from 12/16 to 01/14	Payni from 14/15 au 05/14
Athyr (Athyr in Copte)from 09/17 to 10/16	Phaménoth from 01/15 to 02/13	Epiphi from 05/15 to 06/13
Choiak (or Choiak) from 10/17 to 11/15	Parmuthi from 02/14 to 03/15	Mesori from 06/14 to 07/13

uses a different era. The French Republican Calendar was similar, but began its year at the Autumnal Equinox. British Orrery maker John Gleave represented the Egyptian calendar in a reconstruction of the Antikythera mechanism.

In 285 BCE The Egyptian calendar was not even at a similar stage of development of the Vedic calendar which was superseded by the Vedāńga Jyotiṣa calendar sometime between 1861 and 1350 BCE.

TABLE 2 NAMES OF MONTHS IN EGYPT AND GREECE

No.	Seasonal Names	Middle Kingdom	New Kingdom	Greek	Coptic	Egyptian Arabic	
						Latin script	Arabic script
I	First of *Akhet*	Tekh	Dhwt	Thoth	Thout	Tout	توت
II	Second of *Akhet*	Menhet	Pa-n-ip.t	Phaophi	Paopi	Baba	بابه
III	Third of *Akhet*	Hwt-hwr	Hwt-hwr	Athyr	Hathor	Hatour	هاتور
IV	Fourth of *Akhet*	Ka-hr-ka	Ka-hr-ka	Choiak	Koiak	Kiahk	كياك (كيهك)
V	First of *Peret*	Sf-bdt	Ta-'b	Tybi	Tobi	Touba	طوبه
VI	Second of *Peret*	Rekh wer	Mḫyr	Mechir	Meshir	Amshir	أمشير
VII	Third of *Peret*	Rekh neds	Pa-n-amn-htp.w	Phamenoth	Paremhat	Baramhat	برمهات
VIII	Fourth of *Peret*	Renwet	Pa-n-rnn.t	Pharmouthi	Paremoude	Baramouda	برموده
IX	First of *Shemu*	Hnsw	Pa-n-ḫns.w	Pachon	Pashons	Bashans	بشنس
X	Second of *Shemu*	Hnt-htj	Pa-n-in.t	Payni	Paoni	Ba'ouna	بئونه
XI	Third of *Shemu*	Ipt-hmt	Ipip	Epiphi	Epip	Abib	أبيب
XII	Fourth of *Shemu*	Wep-renpet	Msw-r'	Mesore	Mesori	Mesra	

TABLE 3 THE BABYLONIAN ZODIAC				
Number	Babylonian Month name	Translation of name	Constellation	The Indian Rāśi
	Nisanu	The hired man	Aries	Meṣa
	Ajaru	The stars, The Bull of heaven	Pleiades, Taurus	Vṛṣabha
	Simanu	The true shepherd of Anu. The great twins	Orion, Gemini	Mithuna
	Duuzu	The Crab	Cancer	Karka (Greek Kaarkinos)
	Abu	The Lion	Leo	Simha
	Ululu	The barley stalk	Virgo	Kanya
	Tashritu	The balance	Libra	Tula
	Arahsamna	The scorpion	Scorpio	Vrushchik
	Kislimu	Pabisag	Sagittarius	Dhanu
	Tebetu	The goat fish	Capricorn	Makara
	Shabatu	The giant	Aquarius	Kumbha
	Adaru	The field, the tails	Pegasus, Pisces	Mīna

THE BABYLONIAN CALENDAR

However, the Babylonian calendar remained chaotic throughout most of the first millennium BC due to the irregular insertion of random months. The Babylonian year apparently consisted originally of 12 months of 30^d, but sometimes made use of sightings of the crescent moon to name the beginning of a month. Under Nabonassar (747-734 BC), a fixed-length month of 30^d was used. The Babylonians finally systematized a strictly lunar calendar which began with the first visible crescent moon around 500 BC.

THE HEBREW CALENDAR

As it exists today, the Hebrew calendar is a lunisolar calendar that is based on calculation rather than observation. This calendar is the official calendar of Israel and is the liturgical calendar of the Jewish faith.

In principle the beginning of each month is determined by a tabular New Moon (*molad*) that is based on an adopted mean value of the lunation cycle. To ensure that religious festivals occur in appropriate seasons, months are intercalated according to the Metonic cycle, in which 235 lunations occur in nineteen years.

By tradition, days of the week are designated by number, with only the seventh day, Sabbath, having a specific name. Days are reckoned from sunset to sunset, so that day 1 begins at sunset on Saturday and ends at sunset on Sunday. The Sabbath begins at sunset on Friday and ends at sunset on Saturday.

Rules

Years are counted from the Era of Creation, or Era Mundi, which corresponds to -3760 October 7 on the Julian proleptic calendar. Each year consists of twelve or thirteen months, with months consisting of 29^d or 30^d. An intercalary month is introduced in years 3, 6, 8, 11, 14, 17, and 19 in a nineteen-year cycle of 235 lunations. The initial year of the calendar, A.M. (Anno Mundi) 1, is year 1 of the nineteen-year cycle.

The calendar for a given year is established by determining the day of the week of Tishri 1 (first day of Rosh Hashanah or New Year's Day) and the number of days in the year. Years are classified according to the number of days in the year (see Table 4).

TABLE 4 CLASSIFICATION OF YEARS IN HEBREW CALENDAR

	Deficient	Regular	Complete
Ordinary year	353	354	355
Leap year	383	384	385

* In a complete year, Heshvan has 30^d. ** In a deficient year, Kislev has 29^d. *** In a leap year Adar I have 30^d; it is followed by Adar II with 29^d.

Deficient (*haser*) month: a month comprising 29^d.

Full (*male*) month: a month comprising 30^d
Ordinary year: a year comprising 12^m, with a total of 353, 354, or 355^d.
Leap year: a year comprising 13^m, with a total of 383, 384, or 385^d.
Complete year (*shelemah*): a year in which the months of *Heshvan* and *Kislev* both contain 30^d.
Deficient year (*haser*): a year in which the months of *Heshvan* and *Kislev* both contain 29^d.
Regular year (*kesidrah*): a year in which *Heshvan* has 29^d *Kislev* has 30^d.
Halakim (singular, *helek*): "parts" of an hour; there are 1080 *halakim* per hour.
Molad(plural, *moladot*): "birth" of the Moon , taken to mean the time of conjunction for modern calendric purposes.
Dehiyyah (plural, *dehiyyot*): "postponement"; a rule delaying 1 *Tishri* until after the *molad*.

TERMINOLOGY OF THE HEBREW CALENDAR
TABLE 5 MONTHS OF THE HEBREW CALENDAR

TABLE 5 MONTHS OF THE HEBREW CALENDAR

1. Tishri	30	7. Nisan	30
2. Heshvan	29*	8. Iyar	29
3. Kislev	30**	9. Sivan	30
4. Tevet	29	10. Tammuz	29
5. Shevat	30	11. Av	30
6. Adar	29***	12. Elul	29

The months of Heshvan and Kislev vary in length to satisfy requirements for the length of the year (see Table 4). In leap years, the 29-day month Adar is designated Adar II, and is preceded by the 30-day intercalary month Adar I.
For calendrical calculations, the day begins at 6 P.M., which is designated 0 hours. Hours are divided into 1080 *halakim*; thus one *helek* is 3 1/3 seconds. Calendrical calculations are referred to the meridian of Jerusalem -- 2 hours 21 minutes east of Greenwich.
Rules for constructing the Hebrew calendar are given in the sections that follow. Cohen (1981), Resnikoff (1943), and Spier (1952) provide reliable guides to the rules of calculation.

DETERMINING TISHRI 1

The calendar year begins with the first day of Rosh Hashanah (Tishri 1). This is determined by the day of the Tishri *molad* and the four rules of postponements (*dehiyyot*). The *dehiyyot* can postpone Tishri 1 until one or two days following the *molad*. Tabular new Moon s (*maladot*) are reckoned from the Tishri *molad* of the year A.M. 1, which occurred on day 2 at 5 hours, 204 *halakim* (i.e., 11:11:20 P.M. on Sunday, -3760 October 6, Julian proleptic calendar). The adopted value of the mean lunation is $29^d 12^h$, 793 *halakim* (29.530594^d). To avoid rounding and truncation errors, calculation should be

TABLE 6 LUNATION CONSTANTS IN A HEBREW CALENDAR		
Lunations		**Weeks-Days-Hours-*Halakim***
1	=	4-1-12-0793
12	=	50-4-08-0876
13	=	54-5-21-0589
235	=	991-2-16-0595

done in *halakim* rather than decimals of a day, since the adopted lunation constant is expressed exactly in *halakim*.

Lunation constants required in calculations are shown in Table 6 By subtracting off the weeks, these constants give the shift in weekdays that occurs after each cycle.

The *dehiyyot* are as follows: (a) If the Tishri *molad* falls on day 1, 4, or 6, then Tishri 1 is postponed one day. (b) If the Tishri *molad* occurs at or after 18 hours (i.e., noon), then Tishri 1 is postponed one day. If this causes Tishri 1 to fall on day 1, 4, or 6, then Tishri 1 is postponed an additional day to satisfy *dehiyyah* (a). (c) If the Tishri *molad* of an ordinary year (i.e., of twelve months) falls on day 3 at or after 9 hours, 204 *halakim*, then Tishri 1 is postponed two days to day 5, thereby satisfying *dehiyyah* (a). (d) If the first *molad* following a leap year falls on day 2 at or after 15 hours, 589 *halakim*, then Tishri 1 is postponed one day to day 3.

REASONS FOR THE DEHIYYOT

Dehiyyah (a) prevents Hoshana Rabba (Tishri 21) from occurring on the Sabbath and prevents Yom Kippur (Tishri 10) from occurring on the day before or after the Sabbath.

Dehiyyah (b) is an artifact of the ancient practice of beginning each month with the sighting of the lunar crescent. It is assumed that if the *molad* (i.e., the mean conjunction) occurs after noon, the lunar crescent cannot be sighted until after 6 P.M., which will then be on the following day.

Dehiyyah (c) prevents an ordinary year from exceeding 355^d. If the Tishri *molad* of an ordinary year occurs on Tuesday at or after 3:11:20 A.M., the next Tishri *molad* will occur at or after noon on Saturday. According to *dehiyyah* (b), Tishri 1 of the next year must be postponed to Sunday, which by *dehiyyah* (a) occasions a further postponement to Monday. This results in an ordinary year of 356^d. Postponing Tishri 1 from Tuesday to Thursday produces a year of 354^d.

Dehiyyah (d) prevents a leap year from falling short of 383^d. If the Tishri *molad* following a leap year is on Monday, at or after 9:32:43 1/3 A.M., the previous Tishri *molad* (thirteen months earlier) occurred on Tuesday at or after noon. Therefore, by *dehiyyot* (b) and (a), Tishri 1 beginning the leap year was postponed to Thursday. To prevent a leap year of 382^d, *dehiyyah* (d) postpones by one day the beginning of the ordinary year.

A thorough discussion of both the functional and religious aspects of the *dehiyyot* is provided by Cohen (1981).

3.1.3 Determining the Length of the Year

An ordinary year consists of 50 weeks plus 3, 4, or 5 days. The number of excess days identifies the year as being deficient, regular, or complete, respectively. A leap year consists of 54 weeks plus 5, 6, or 7 days, which again are designated deficient, regular, or complete, respectively. The length of a year can therefore be determined by comparing the weekday of Tishri 1 with that of the next Tishri 1.

First consider an ordinary year. The weekday shift after twelve lunations is 04-08-876. For example if a Tishri *molad* of an ordinary year occurs on day 2 at 0 hours 0 *halakim* (6 P.M. on Monday), the next Tishri *molad* will occur on day 6 at 8 hours 876 *halakim*. The first Tishri *molad* does not require

application of the *dehiyyot*, so Tishri 1 occurs on day 2. Because of *dehiyyah* (a), the following Tishri 1 is delayed by one day to day 7, five weekdays after the previous Tishri 1. Since this characterizes a complete year, the months of Heshvan and Kislev both contain 30^{d}. The weekday shift after thirteen lunations is 05-21-589. If the Tishri *molad* of a leap year occurred on day 4 at 20 hours 500 *halakim*, the next Tishri *molad* will occur on day 3 at 18 hours 9 *halakim*. Because of *dehiyyot* (b), Tishri 1 of the leap year is postponed two days to day 6. Because of *dehiyyot* (c), Tishri 1 of the following year is postponed two days to day 5. This six-day difference characterizes a regular year, so that Heshvan has 29^{d} and Kislev has 30^{d}.

HISTORY OF THE HEBREW CALENDAR

The codified Hebrew calendar as we know it today is generally considered to date from A.M. 4119 (+359), though the exact date is uncertain. At that time the patriarch Hillel II, breaking with tradition, disseminated rules for calculating the calendar. Prior to that time the calendar was regarded as a secret science of the religious authorities. The exact details of Hillel's calendar have not come down to us, but it is generally considered to include rules for intercalation over nineteen-year cycles. Up to the tenth century CE, however, there was disagreement about the proper years for intercalation and the initial epoch for reckoning years.

Information on calendrical practices prior to Hillel is fragmentary and often contradictory. The earliest evidence indicates a calendar based on observations of Moon phases. Since the Bible mentions seasonal festivals, there must have been intercalation. There was likely an evolution of conflicting calendrical practices.

The Babylonian exile, in the first half of the sixth century BCE, greatly influenced the Hebrew calendar. This is visible today in the names of the months. The Babylonian influence may also have led to the practice of intercalating leap months.

FIGURE 1 THE MAYAN CALENDAR. THE TZOLKIN

During the period of the Sanhedrin, a committee of the Sanhedrin met to evaluate reports of sightings of the lunar crescent. If sightings were not possible, the new month was begun 30^{d} after the beginning

of the previous month. Decisions on intercalation were influenced, if not determined entirely, by the state of vegetation and animal life. Although eight-year, nineteen-year, and longer- period intercalation cycles may have been instituted at various times prior to Hillel II, there is little evidence that they were employed consistently over long time spans.

The Mayan approach to the measurement of time comes in 3 flavors. But before we get into the details it must be mentioned that the Mayan achievements in diverse areas of art, sculpture, architecture, mathematics and astronomy, indicates a high level of technology and sophistication. While the Mayans were no longer in control when Hernan Cortez came with his gang of bandits, the sight that met their eyes when they first laid eyes on Teotihuacan, which was ruled by the Aztecs, it was enough to dazzle the most jaded traveler. Never had the Spaniards witnessed such splendor as that which unfolded in front of their eyes when they got the first glimpse of the city on the lake.

The Mayans were great builders and had discovered the use of cement as a building material and they used their buildings very effectively to make more observations of the planets. The Mayans had a particular affinity for Venus. Their number for the synodic revolution of Venus was 584^d compared to the modern value of 583.02. They made their own measurements of the solar year and came up with 365.242 days, which compares very favorably with the modern value of 365.242198. In fact there number was more accurate than the number that is used today by the Gregorian calendar, namely 365.2425. For the synodic month the Mayan astronomers of Copan observed that there were 149 new moons in $4,400^d$, giving a synodic month of 29.5302^d. At Palenque, the same calculation was made over 81 new moons and produced the even more accurate figure of 2392^d, giving a value of 29.53086^d.

The Mayan civilization was fully developed by the 3rd Century BCE, but it must have reached a stage of maturity long before that. Figure shows the extent of the Mayan civilization comprising 325,000 square kilometers. It includes the following areas.

the present day Mexican provinces of Tabasco, Campeche, and Yucatan,
the region of Quintana Roo, and a part of Chiapas province,
the Peten region and almost all the uplands of Guatemala,
the whole of Belize formerly known as British Honduras,
the western half of San Salvador, parts of Honduras.

There are about 2 million descendants of the Maya remaining extant today.
The Number System used by the Maya was vigesimal (base 20) but in order to accommodate the number 360, the third place has only 18 units rather than 20'.

1 kin = 1 day	**1 pictun = $2,880,000^d$ or 20 baktuns**
1 winal = 20 Kin or 20^d	1 calabtun = $57,600,000^d$ or 20 pictuns
1 tun = 360^d or 18 winals	1 kinchiltun = $1,152,000,000^d$ or 20 calabtun
1 katun = $7,200^d$ or 20 tuns	1 alautun = $23,040,000,000^d$ = 20kinchiltun
1baktun = $144,000^d$ or 20 katuns	

The Mayans used various cycles to express and record their time. They used 2 calendars, one for religious purposes, and one for civil use.

THE TZOLKIN

TABLE 7 THE MAYAN TZOLK'IN CALENDAR: NAMED DAYS AND ASSOCIATED GLYPHS

Seq. N°[1]	Day Name[2]	Glyph example[3]	16th C. Yucatec[4]	reconstructed Classic Maya[5]	Seq. N°[1]	Day Name[2]	Glyph example[3]	16th C. Yucatec[4]	reconstructed Classic Maya[5]
01	Imix'		Imix	Imix (?) / Ha' (?)	11	Chuwen		Chuen	(unknown)
02	Ik'		Ik	Ik'	12	Eb'		Eb	(unknown)
03	Ak'b'al		Akbal	Ak'b'al (?)	13	B'en		Ben	(unknown)
04	K'an		Kan	K'an (?)	14	Ix		Ix	Hix (?)
05	Chikchan		Chicchan	(unknown)	15	Men		Men	(unknown)
06	Kimi		Cimi	Cham (?)	16	K'ib'		Cib	(unknown)
07	Manik'		Manik	Manich' (?)	17	Kab'an		Caban	Chab' (?)
08	Lamat		Lamat	Ek' (?)	18	Etz'nab'		Etznab	(unknown)
09	Muluk		Muluc	(unknown)	19	Kawak		Cauac	(unknown)
10	Ok		Oc	(unknown)	20	Ajaw		Ahau	Ajaw

***NOTES:* THE SEQUENCE NUMBER OF THE NAMED DAY IN THE TZOLK'IN CALENDAR**

Day name, in the standardized and revised orthography of the Guatemalan Academia de Lenguas Mayas

An example glyph (logogram) for the named day. Note that for most of these several different forms are recorded; the ones shown here are typical of carved monumental inscriptions (these are "cartouche" versions)

Day name, as recorded from 16th century Yukatek Maya accounts, principally Diego de Landa; this orthography has (until recently) been widely used

In most cases, the actual day name as spoken in the time of the Classic Period (ca. 200–900) when most inscriptions were made is not known. The versions given here (in Classic Maya, the main language of the inscriptions) are reconstructed on the basis of phonological evidence, if available; a '?' symbol indicates the reconstruction is tentative.

The Tzolkin, which is the religious calendar, consists of 260^{d}. A day in the Tzolkin calendar consists of 2 descriptors – a numerical portion from 1 to 13 and a day name. The day sequence starts from Imix and runs through Ahau

The *tzolk'in* (in modern Maya orthography; also commonly written *tzolkin*) is the name commonly employed by Mayanist researchers for the Maya Sacred Round or 260-day calendar. The word *tzolk'in* is a neologism coined in Yucatec Maya, to mean "count of days" (Coe 1992). The various names of this calendar as used by Precolumbian Maya peoples are still debated by scholars. The Aztec calendar equivalent was called *Tonalpohualli*, in the Nahuatl language.

The tzolk'in calendar combines twenty day names with the thirteen numbers of the *trecena* cycle to produce 260 unique days. It is used to determine the time of religious and ceremonial events and for divination. Each successive day is numbered from 1 up to 13 and then starting again at 1. Separately from this, every day is given a name in sequence from a list of 20 day names:

THE HAAB

The Haab calendar is the second calendar that the Mayans used for civil purposes. It consists of a 365 day cycle that is composed of 18 months of 20^{d} each, followed by a 5 day residual period called the Wayeb or the Unlucky days. This is not very different from the earliest Vedic calendar. Thus the Maya could represent any day in two different ways and the synchronization of the two days which would occur after 18980 days (which as we can verify is the LCM of the 2

Figure 2 The Long Count of the Maya numbers).

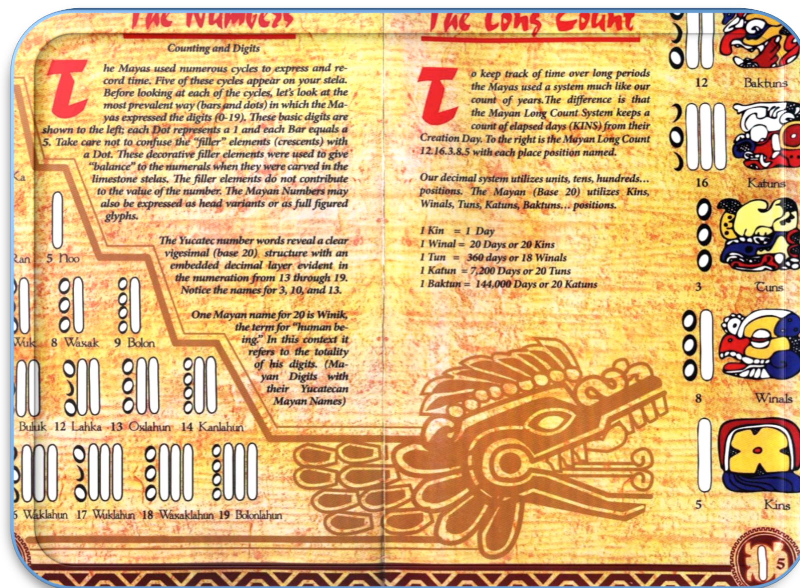


FIGURE 2 THE LONG DAY COUNT OF THE MAYAN

LCM = $(N_1 * N_2)$/GCF = 260*365/5 = 18,980^d

THE LONG DAY COUNT

Then there is the third system of keeping time, the long count. This is very similar in concept to the Vedic Ahargana system, which we are almost certain, was emulated by Scaliger when he came up with the Julian day count.

For example, the Long count 12, 16, 3, 8, 5 equals 1,844,445^d as shown below

12 baktuns = 12 *144,000 = 1,728,000^d

16 katuns = 16 * 7200 = 115,200^d

3 tuns = 3*360 = 1,080^d

8 winals = 8*20 = 160^d

5 kins = 5*1 = 5^d

Total = 1,844,445^d from the beginning of the great era



According to the Goodman Martinez Thompson correlation the beginning date is August 11, -3113 (BCE) proleptic Gregorian or September 6, 3114 BCE (Julian) or 584283 JD (Julian day count) or -1,137,142 (RD, rata die, elapsed days since Monday, January 1, 1).

THE CHINESE CALENDAR

FIGURE 3 THE LOCATION OF THE MAYAN PEOPLE

The Chinese calendar is a lunisolar calendar based on astronomical events and calculations of the positions of the Sun and Moon, and not on arithmetical rules. The days begin at civil midnight; the months are lunar and begin with the new moon. There are 12 or 13 months in a year. With the number of months determined by the number of months between 2 successive winter solstices. There are many excellent references on the Chinese calendar in the appendix and the reader is requested to refer to those. For example there is an expository paper by Helmet Isakson and his students at the National University of Singapore[261]. We will merely highlight the rules of the calendar.

Months of 29 or 30^d begin on days of astronomical New Moons, with an intercalary month being added every two or three years. Since the calendar is based on the true positions of the Sun and Moon, the accuracy of the calendar depends on the accuracy of the astronomical theories and calculations.

Although the Gregorian calendar is used in the Peoples' Republic of China for administrative purposes, the traditional Chinese calendar is used for setting traditional festivals and for timing agricultural activities in the countryside. The Chinese calendar is also used by Chinese communities around the world. Rule 1 *Calculations are based on the meridian* 120$^{\prime}$ *East* Before 1929 the computations were

[261] *Veronica Chin Hei Ting, Raffles Junior College, The Mathematics of the Chinese Calendar, 1999.*

based on the meridian in Beijing, 116$^{\prime}$25^{0} East, but in 1928 China adopted a standard time zone based on 120$^{\prime}$ East, which is close to the longitude of the republican capital

Nanjing, 118$^{\prime}$46^{0} East. Since 1929 the Institute of Astronomy in Nanjing, and since 1949 the Purple Mountain Observatory, (Zˇıjˉınshˉanwéntái) outside TiˉNanjing has been responsible for calendrical calculations in China. This change in base meridian has caused a lot of confusion.

TABLE 8 CHINESE SEXAGENARIAN CYCLE OF DAYS AND YEARS	
Celestial Stems	Earthly Branches
1. jail	1. zi (rat)
2. yi	2. chou (ox)
3. bing	3. yin (tiger)
4. ding	4. mao (hare)
5. wu	5. chen (dragon)
6. ji	6. si (snake)
7. geng	7. wu (horse)
8. xin	8. wei (sheep)
9. ren	9. shen (monkey)
10. gui	10. you (fowl)
	11. xu (dog)
	12. hai (pig)

Rule 2 The *Chinese day starts at midnight.* The Chinese system of 12 double hours starts at 11 p.m. This is important in Chinese astrology. Your date and time of birth is determined by the eight characters, bazì, formed by the pair of cyclical characters for the year, month, day, and hour. But for calendrical purposes, the day starts at midnight.

Rule 3 The *day on which a new Moon occurs is the first day of the new month.*

Notice that the new month takes the whole day, no matter what time of the day conjunction occurs. So even if the new Moon takes place late in the evening, the whole day is considered to be part of the new month, and if a zhongqì occurred in the early morning, it is considered as having fallen in the new month, even though it may have occurred almost 24 hours before the new Moon. The lengths of the months are determined astronomically (Table 6). Suppose a month is 29.5^{d} and starts with a new Moon at 13h on May 1. The next new Moon then takes place at 1h on May 31, so the month has 30^{d}. But if the new Moon occurred at ^{1h} on May 1, then the next new Moon would be at 13^{h} on May 30, so the new month would start one day earlier, and we would only get 29^{d} in the month. The Chinese system of 12 double hours starts at 11 PM.

TABLE 9 THE CHINESE NAME FOR THE YEAR

Jiǎzǐ (甲子) sequence	Stem/ branch	Gānzhī (干支)	Year of the...	Continuous[1]	Gregorian[2]	New Year's Day (chūnjié, 春節)
1	1/1	jiǎzǐ (甲子)	Wood Rat	4681	1984	February 2
2	2/2	yǐchǒu (乙丑)	Wood Ox	4682	1985	February 20
3	3/3	bǐngyín (丙寅)	Fire Tiger	4683	1986	February 9
4	4/4	dīngmǎo (丁卯)	Fire Hare	4684	1987	January 29
5	5/5	wùchén (戊辰)	Earth Dragon	4685	1988	February 17
6	6/6	jǐsì (己巳)	Earth Snake	4686	1989	February 6
7	7/7	gēngwǔ (庚午)	Metal Horse	4687	1990	January 27
8	8/8	xīnwèi (辛未)	Metal Sheep	4688	1991	February 15
9	9/9	rénshēn (壬申)	Water Monkey	4689	1992	February 4
10	10/10	guǐyǒu (癸酉)	Water Rooster	4690	1993	January 23
11	1/11	jiǎxū (甲戌)	Wood Dog	4691	1994	February 9
12	2/12	yǐhài (乙亥)	Wood Pig	4692	1995	January 31

13	3/1	bǐngzǐ (丙子)	Fire Rat	4693	1996	February 19
14	4/2	dīngchǒu (丁丑)	Fire Ox	4694	1997	February 7
15	5/3	wùyín (戊寅)	Earth Tiger	4695	1998	January 28
16	6/4	jǐmǎo (己卯)	Earth Hare	4696	1999	February 16
17	7/5	gēngchén (庚辰)	Metal Dragon	4697	2000	February 5
18	8/6	xīnsì (辛巳)	Metal Snake	4698	2001	January 24
19	9/7	rénwǔ (壬午)	Water Horse	4699	2002	February 12
20	10/8	guǐwèi (癸未)	Water Sheep	4700	2003	February 1
21	1/9	jiǎshēn (甲申)	Wood Monkey	4701	2004	January 22
22	2/10	yǐyǒu (乙酉)	Wood Rooster	4702	2005	February 9
23	3/11	bǐngxū (丙戌)	Fire Dog	4703	2006	January 29
24	4/12	dīnghài (丁亥)	Fire Pig	4704	2007	February 18
25	5/1	wùzǐ (戊子)	Earth Rat	4705	2008	February 7
26	6/2	jǐchǒu (己丑)	Earth Ox	4706	2009	January 26
27	7/3	gēngyín (庚寅)	Metal Tiger	4707	2010	February 14

28	8/4	xīnmǎo (辛卯)	Metal Hare	4708	2011	February 3
29	9/5	rénchén (壬辰)	Water Dragon	4709	2012	January 23
30	10/6	guǐsì (癸巳)	Water Snake	4710	2013	February 10
31	1/7	jiǎwǔ (甲午)	Wood Horse	4711	2014	January 31
32	2/8	yǐwèi (乙未)	Wood Sheep	4712	2015	February 19
33	3/9	bǐngshēn (丙申)	Fire Monkey	4713	2016	February 8
34	4/10	dīngyǒu (丁酉)	Fire Rooster	4714	2017	January 28
35	5/11	wùxū (戊戌)	Earth Dog	4715	2018	February 16
36	6/12	jǐhài (己亥)	Earth Pig	4716	2019	February 5
37	7/1	gēngzǐ (庚子)	Metal Rat	4717	2020	January 25
38	8/2	xīnchǒu (辛丑)	Metal Ox	4718	2021	February 12
39	9/3	rényín (壬寅)	Water Tiger	4719	2022	February 1
40	10/4	guǐmǎo (癸卯)	Water Hare	4720	2023	January 22
41	1/5	jiǎchén (甲辰)	Wood Dragon	4721	2024	February 10
42	2/6	yǐsì (乙巳)	Wood Snake	4722	2025	January 29

43	3/7	bǐngwǔ (丙午)	Fire Horse	4723	2026	February 17
44	4/8	dīngwèi (丁未)	Fire Sheep	4724	2027	February 6
45	5/9	wùshēn (戊申)	Earth Monkey	4725	2028	January 26
46	6/10	jǐyǒu (己酉)	Earth Rooster	4726	2029	February 13
47	7/11	gēngxū (庚戌)	Metal Dog	4727	2030	February 3
48	8/12	xīnhài (辛亥)	Metal Pig	4728	2031	January 23
49	9/1	rénzǐ (壬子)	Water Rat	4729	2032	February 11
50	10/2	guǐchǒu (癸丑)	Water Ox	4730	2033	January 31
51	1/3	jiǎyín (甲寅)	Wood Tiger	4731	2034	February 19
52	2/4	yǐmǎo (乙卯)	Wood Hare	4732	2035	February 8
53	3/5	bǐngchén (丙辰)	Fire Dragon	4733	2036	January 28
54	4/6	dīngsì (丁巳)	Fire Snake	4734	2037	February 15
55	5/7	wùwǔ (戊午)	Earth Horse	4735	2038	February 4
56	6/8	jǐwèi (己未)	Earth Sheep	4736	2039	January 24
57	7/9	gēngshēn (庚申)	Metal Monkey	4737	2040	February 12

58	8/10	xīnyǒu (辛酉)	Metal Rooster	4738	2041	February 1
59	9/11	rénxū (壬戌)	Water Dog	4739	2042	January 22
60	10/12	guǐhài (癸亥)	Water Pig	4740	2043	February 10

This is important in Chinese astrology. The date and time of birth is denoted by the eight characters, bazì formed by the pair of cyclical characters for the year, month, day, and hour. But for calendrical purposes, the day starts at midnight. It is important to understand that the Chinese calendar is a combination of two calendars, a solar calendar, and a lunisolar calendar. The solar calendar starts at the December solstice and follows the 24 jiéqì. This is traditionally called the farmer's calendar. The lunisolar calendar starts at Chinese New Year and consists of 12 or 13 months. This is what most people think of as the Chinese calendar, but unfortunately the term farmer's calendar has come to include the lunisolar calendar. The Chinese solar calendar follows the tropical year closely, so it is perfect for farming purposes, but the lunisolar calendar is not at all suitable for farmers. There are therefore two different years in the Chinese calendar, the suì and the nián. A *suì* is the solar year from one December solstice to the next. This is similar to the tropical year (except that in Western astronomy the tropical year was traditionally measured from one March equinox to the next). A *nián* is the Chinese year from one Chinese New Year to the next. Since a Chinese year can contain 12 or 13 lunar months, and they can each have 29 or 30^d, the length of a nián can be 353, 354 or 355 in case of a normal year and 383, 384 or 385^d in case of a leap year. There are many conflicting figures for the number of days in a Chinese year. Tang ([52]) does not include 385, but there will be 385^d in 2006. The Chinese also had a system of 28 Hsui which they introduced, probably from India (see chapter on Nakṣatras).

THE ISLAMIC CALENDAR


FIGURE 4, 5 ARMILLARY SPHERES AT THE PURPLE MOUNTAIN OBSERVATORY IN NANJING DESIGNED BY GUO SHOUJING

The Islamic calendar is solely a Lunar calendar in which months correspond to the Lunar phase cycle. As a result, the cycle of twelve Lunar months regresses through the seasons over a period of about 33 years. For religious purposes, Muslims begin the months with the first visibility of the lunar crescent after conjunction. For civil purposes a tabulated calendar that approximates the lunar phase cycle is often used. The seven-day week is observed with each day beginning at sunset. Weekdays are specified by number, with day 1 beginning at sunset on Saturday and ending at sunset on Sunday. Day 5, which is called Jum'a, is the day for congregational prayers. Unlike the Sabbath days of the Christians and Jews, however, Jum'a is not a day of rest. Jum'a begins at sunset on Thursday and ends at sunset on Friday. [Erratum: It appears that Doggett should have stated that Jum'a is Day 6, not Day 5.] Moslem astronomers and mathematicians also went to work, refining the Islamic calendar. This calendar-whose year 1 began in our year CE 622, when Mohammad fled Mecca for Medina-was established by the second Khalīf Umar, around CE 634. Years in the Islamic calendar are indicated with the abbreviation A.H., which from the Latin anno hegirae, or "the Year of the Migration. Since then, it has been running at the standard lunar time of 354[d]

a year, drifting across the seasons to start on the same day every 32 ½ years.

Years of twelve Lunar months are reckoned from the Era of the Hijra, commemorating the migration of the Prophet and his followers from Mecca to Medina. This epoch, 1 A.H. (Anno Higerae) Muharram 1, is generally taken by astronomers (Neugebauer, 1975) to be Thursday, +622 July 15 (Julian calendar). This is called the astronomical Hijra epoch. Chronological tables (e.g., Mayr and Spuler, 1961; Freeman-Grenville, 1963) generally use Friday, July 16, which is designated the civil epoch. In both cases the Islamic day begins at sunset of the previous day.

For religious purposes, each month begins in principle with the first sighting of the lunar crescent after the New Moon. This is particularly important for establishing the beginning and end of Ramadan. Because of uncertainties due to weather, however, a new month may be declared thirty days after the beginning of the preceding month. Although various predictive procedures have been used for determining first visibility, they have always had an equivocal status. In practice, there is disagreement

among countries, religious leaders, and scientists about whether to rely on observations, which are subject to error, or to use calculations, which may be based on poor models.

Chronologists employ a thirty-year cyclic calendar in studying Islamic history. In this tabular calendar, there are eleven leap years in the thirty-year cycle. Odd-numbered months have thirty days and even-numbered months have twenty-nine days, with a thirtieth day added to the twelfth month, Dhu al-Hijjah (see Table 9). Years 2, 5, 7, 10, 13, 16, 18, 21, 24, 26, and 29 of the cycle are designated leap years. This type of calendar is also used as a civil calendar in some Muslim countries, though other years are sometimes used as leap years. The mean length of the month of the thirty-year tabular calendar is about 2.9 seconds less than the synodic period of the Moon .

TABLE 10 MONTHS OF TABULAR ISLAMIC CALENDAR

1. Muharram**	30	7. Rajab**	30
2. Safar	29	8. Sha'ban	29
3. Rabi'a I	30	9. Ramadan***	30
4. Rabi'a II	29	10. Shawwal	29
5. Jumada I	30	11. Dhu al-Q'adah**	30
6. Jumada II	29	12. Dhu al-Hijjah**	29*

* In a leap year, Dhu al-Hijjah has 30^d.
** Holy months.
*** Month of fasting.

The form of the Islamic calendar, as a lunar calendar without intercalation, was laid down by the Prophet in the Qur'an (Sura IX, verse 36-37) and in his sermon at the Farewell Pilgrimage. This was a departure from the lunisolar calendar commonly used in the Arab world, in which months were based on first sightings of the lunar crescent, but an intercalary month was added as deemed necessary.

THE ROMAN CALENDAR

Prior to 46 BCE, the Roman calendar, or what has been reconstructed of it, is described as a "mess." The Roman calendar originally started the year with the vernal equinox and consisted of 10 months (Martius, Aprilis, Maius, Junius, Quntilis, Sextilis, September, October, November, and December) having a total of 304^d. The numbers still embedded in the last four months of the year are the fossil of this (September, October, November, and December, contain the Latin roots for the numerals seven, eight, nine, and ten, but now fall on the ninth, tenth, eleventh and twelfth months of the year). The 304^dwere followed by an unnamed, unnumbered period in winter. The Roman emperor Numa Pompilius (715-673 BC) introduced February and January between January and March, increasing the length of the year to 354 or 355^d. Then in 450 BC, February was moved to its current position.

In the year 46 BC, the Egyptian Astronomer Sosigenes convinced Julius Caesar to reform the calendar to a more manageable form. The Julian calendar consisted of cycles of three 365-day years followed by a 366-day leap year.

TABLE 11 THE MONTHS OF THE ROMAN CALENDAR		
Month	Days	Etymology
January	31	Janus, two-headed god of doorways and gates
February	28/29	Februarius, the month of expiation
March	31	Mars, god of war originally the year started here
April	30	derived from Latin verb meaning "to open"
May	31	Maia, goddess of Spring and growth
June	30	Juno, goddess of wisdom and marriage
July	31	Julius Caesar originally quintilis 5 in Latin
August	31	Augustus Caesar originally sextilis 6 in Latin
September	30	7 in Latin
October	31	8 in Latin
November	30	9 in Latin
December	31	10 in Latin

Although a great improvement over the Metonic calendar, the Julian calendar was still not quite in synchronization with the seasons. The Venerable Bede, an English scholar who lived from 673-735, noted that the vernal equinox had slipped three days earlier than the traditional March 21. The Julian calendar remained in use, however, until replaced by the Gregorian calendar in the late sixteenth century. Although the Roman abbot Dionysius Exiguus proposed that the years be numbered from the birth of Christ in about 524 (Boyer 1968, p. 272), Bede was the first to actually date events from the birth of Christ. This system gives rise to the familiar classification of dates as BC or (also sometimes denoted BCE and CE). Interestingly enough, probably because the concept for zero was not widely used in Europe at the time, this method of dating omits the year zero, so that the year 1 BC is followed immediately by the year 1. In any case, whoever zeroed the calendar made an error, since the Bible says Jesus was alive in Herod's time, but Roman records showed that Herod died in what turns out to be 4 BC.

THE GREGORIAN CALENDAR THAT IS IN UNIVERSAL USE TODAY

The **Gregorian calendar** attempts to keep the vernal equinox on or soon before March 21; hence it follows the vernal equinox. The average length of this calendar's year is 365.2425 mean Solar days (which is equivalent to 97 out of 400 years being leap years; centennial years are not leap years unless divisible by 400)) whereas the vernal equinox year is 365.2424[d].

The word "tropical" comes from the Greek *tropos* meaning "turn". The tropics of Cancer and Capricorn mark the extreme north and south latitudes where the Sun can appear directly overhead. The position of the Sun can be measured by the variation from day to day of the length of the shadow at noon of a gnomon (a vertical pillar or stick). For most daily requirements this is the most "natural" way to measure the year in the sense that these variations drive the seasons.

But the interesting artifact is that the Gregorian Calendar (see the Glo-pedia in Appendix A) was promulgated by the Vatican at the behest of Pope Gregory only in 1582 CE. The reason was that the

measure of a tropical year was not known to a degree of accuracy that was needed to keep the various Religious observances like Easter occurring at a certain date in the calendar. The question that we pose is why did it take 2000 years to fix this calendar, if in fact this data was available to the ancient Greeks as is alleged by David Pingree, who asserted with a great deal of certainty, that the Indians obtained it from the Greeks[262].The answer seems to lie in the delegation of Jesuit priests that Christopher Clavius sent to Malabar in 1560 CE in order to learn the intricacies of the Indian Jyotiṣa. Clearly the assumption that David Pingree makes is the result of a fevered imagination, resulting from a false assumption as to the prowess of the Greeks. See Chapter IX for the overall thrust of David Pingree's work.

The Gregorian calendar today serves as an international standard for civil use. In addition, it regulates the ceremonial cycle of the Roman Catholic and Protestant churches. In fact, its original purpose was ecclesiastical. Although a variety of other calendars are in use today, they are restricted to particular religions or cultures. Years are counted from the initial epoch defined by Dionysius Exiguus, and are divided into two classes: common years and leap years. A common year is 365^d in length; a leap year is 366^d, with an intercalary day, designated February 29, proceeding March 1. Leap years are determined according to the following rule: Every year that is exactly divisible by 4 is a leap year, except for years that are exactly divisible by 100; these centurial years are leap years only if they are exactly divisible by 400. As a result the year 2000 is a leap year, whereas 1900 and 2100 are not leap years. These rules can be applied to times prior to the Gregorian reform to create a proleptic Gregorian calendar. In this case, year 0 (1 BCE) is considered to be exactly divisible by 4, 100, and 400, and hence it is a leap year. The Gregorian calendar is thus based on a cycle of 400 years, which comprises 146097^d . Since 146097 is evenly divisible by 7, the Gregorian civil calendar exactly repeats after 400 years. Dividing 146097 by 400 yields an average length of 365.2425^d per calendar year, which is a close approximation to the length of the tropical year? Comparison with the true value of 365.2422 reveals that the Gregorian calendar accumulates an error of one .0003 in 1 year. Although various adjustments to the leap-year system have been proposed, none has been instituted. Within each year, dates are specified according to the count of days from the beginning of the month. The order of months and number of days per month were adopted from the Julian calendar.

TABLE 12 MONTHS OF THE GREGORIAN CALENDAR			
1. January	**31**	**7. July**	**31**
2. February	**28***	**8. August**	**31**
3. March	**31**	**9. September**	**30**
4. April	**30**	**10. October**	**31**
5. May	**31**	**11. November**	**30**

[262] The average length of the tropical year used in the Sūrya Siddhānta is described as 365.2421756 days, which is only 1.4 seconds shorter than the modern value of 365.2421904 days (J2000), the Siddhāntic value being .0000196% different from the value accepted on the epoch of the year 2000 CE. This estimate remained the most accurate approximation for the length of the tropical year anywhere in the world for at least another six centuries, until Muslim mathematician Omar Khayyam gave a better approximation, though it still remains more accurate *than the value given by the modern Gregorian calendar currently in use around the world, which gives the average length of the year as 365.2425 days.*

6. June	**30**	**12. December**	**31**

* In a leap year, February has 29^d.

The ecclesiastical calendars of Christian churches are based on cycles of movable and immovable feasts. Christmas is the principal immovable feast, with its date set at December 25. Easter is the principal movable feast, and dates of most other movable feasts are determined with respect to Easter. However, the movable feasts of the Advent and Epiphany seasons are Sundays reckoned from Christmas and the Feast of the Epiphany, respectively.

In the Gregorian calendar, the date of Easter is defined to occur on the Sunday following the ecclesiastical Full Moon that falls on or next after March 21. This should not be confused with the popular notion that Easter is the first Sunday after the first Full Moon following the vernal equinox. In the first place, the vernal equinox does not necessarily occur on March 21. In addition, the ecclesiastical Full Moon is not the astronomical Full Moon -- it is based on tables that do not take into account the full complexity of Lunar motion. As a result, the date of an ecclesiastical Full Moon may differ from that of the true Full Moon. However, the Gregorian system of leap years and Lunar tables does prevent progressive departure of the tabulated data from the astronomical phenomena.

TABLE 13 TO FIND THE DATE OF EASTER

Given Y = Gregorian Year, to find M= month, D= day

C = Y/100,
N = Y - 19*(Y/19),
K = (C - 17)/25,
I = C - C/4 - (C - K)/3 + 19*N + 15,
I = I - 30*(I/30),
I = I - (I/28)*(1 - (I/28)*(29/(I + 1))*((21 - N)/11)),
J = Y + Y/4 + I + 2 - C + C/4,
J = J - 7*(J/7),
L = I - J,
M = 3 + (L + 40)/44,
D = L + 28 - 31*(M/4).

The ecclesiastical Full Moon is defined as the fourteenth day of a tabular lunation, where day 1 corresponds to the ecclesiastical New Moon . The tables are based on the Metonic cycle, in which 235 mean synodic months occur in 6939.688^d. Since nineteen Gregorian years is 6939.6075^d the dates of Moon phases in a given year will recur on nearly the same dates nineteen years later. To prevent the 0.08 day difference between the cycles from accumulating, the tables incorporate adjustments to synchronize the system over longer periods of time. Additional complications arise because the tabular lunations are of 29 or 30 integral days. The entire system comprises a period of 5700000 years of 2081882250^d which is equated to 70499183 lunations. After this period, the dates of Easter repeat themselves.

The following algorithm for computing the date of Easter is based on the algorithm of Oudin (1940). It is valid for any Gregorian year, Y. All variables are integers and the remainders of all divisions are dropped. The final date is given by M, the month, and D, the day of the month.

TABLE 14 DATES CORRESPONDING TO GREGORIAN DATE JANUARY 1, 1989

Calendar	Year for Gregorian 1989	Year Begins
Byzantine	**7498**	**Sept. 14, 1989**
Chinese	**(4626)**	**Feb. 6, 1989**

Diocletian	**1706**	**Sept. 11, 1989**
Grecian (Seleucid)	**2301**	**Sept. 14 or Oct. 14, 1989**
Indian (Šaka)	**1911**	**Mar. 22, 1989**
Islamic	**1410**	**Aug. 3, 1989***
Japanese	**2649**	**Jan. 1, 1989**
Jewish	**5750**	**Sept. 29, 1989***
Julian	**1989**	**Jan. 14, 1989**
Nabonassar	**2738**	**Apr. 26, 1989**
Roman	**2742**	**Jan. 14, 1989**

(*begins at sunset) .

The Gregorian calendar resulted from a perceived need to reform the method of calculating dates of Easter. Under the Julian calendar the dating of Easter had become standardized, using March 21 as the date of the equinox and the Metonic cycle as the basis for calculating Lunar phases. By the thirteenth century it was realized that the true equinox had regressed from March 21 (the supposed date at the time of the Council of Nicaea, +325) to a date earlier in the month. As a result, Easter was drifting away from its springtime position and was losing its relation with the Jewish Passover. Over the next four centuries, scholars debated the "correct" time for celebrating Easter and the means of regulating this time calendrical. The Church made intermittent attempts to solve the Easter question, without reaching a consensus.

By the sixteenth century the equinox had shifted by ten days, and astronomical New Moon s were occurring four days before ecclesiastical New Moon s. At the behest of the Council of Trent, Pope Pius V introduced a new Breviary in 1568 and Missal in 1570, both of which included adjustments to the lunar tables and the leap-year system. Pope Gregory XIII, who succeeded Pope Pius in 1572, soon convened a commission to consider reform of the calendar, since he considered his predecessor's measures inadequate.

The recommendations of Pope Gregory's calendar commission were instituted by the papal bull "Inter Gravissimus," signed on 1582 February 24. Ten days were deleted from the calendar, so that 1582 October 4 was followed by 1582 October 15, thereby causing the vernal equinox of 1583 and subsequent years to occur about March 21. And a new table of New Moon s and Full Moon s was introduced for determining the date of Easter.

Subject to the logistical problems of communication and governance in the sixteenth century, the new calendar was promulgated through the Roman-Catholic world. Protestant states initially rejected the calendar, but gradually accepted it over the coming centuries. The Eastern Orthodox churches rejected the new calendar and continued to use the Julian calendar with traditional lunar tables for calculating Easter. Because the purpose of the Gregorian calendar was to regulate the cycle of Christian holidays, its acceptance in the non-Christian world was initially not at issue. But as international communications developed, the civil rules of the Gregorian calendar were gradually adopted around the world. Anyone seriously interested in the Gregorian calendar should study the collection of papers resulting from a conference sponsored by the Vatican to commemorate the four-hundredth anniversary of the Gregorian Reform (Coyne et al., 1983). Table 14 gives the dates corresponding to January 1, 1989 in the Gregorian calendar for various other calendar systems *(Astronomical Almanac).*

CHAPTER XI
BIOGRAPHIC HIGHLIGHTS OF SELECTED INDIC SAVANTS[263]

In this concluding chapter we will give brief biographical sketches of several of these gentlemen whom we have listed in the tables below. In reality such an enterprise would result in an encyclopedia of several volumes, if we did justice to each and every one of them. We are not happy that we have to be selective about the individuals we chose as well as the content.

A few remarks are in order regarding the categorization of the literary work after the beginning of the Common Era.

The Siddhāntas are at the top of the totem pole in terms of the authoritativeness of their texts. Obviously a latter Siddhānta carries more weight than an earlier one. They supply the theoretical justification for pursuing a methodology. As we mentioned earlier there were originally 18 Siddhāntas out of which only 5 survived by the time of Varāhamihīra.

Tāntras deal with astronomical computations with reference to the beginning of the Kaliyuga. They give simplified and short rules for computations, e.g. Sumati tantra, Tantra Sangraha.

The Karana texts which were essentially manuals for developing Panchāngams and incorporate epoch based computations for the era in question. E.g. Karanakutūhalam of Bhāskarāchārya. The Āryabhaţīya is a Karana text.

Vyākhyā, vṛtti, bhāṣya, or Commentaries are pedagogical in nature. The Siddhāntic texts are terse and Sūtra like in brevity of expression, and need pedagogical supplements even for experts. They form the content of what we would term text books today.

In those instances where they felt the need, they also wrote text books on the underlying discipline, such as Gaṇita, PatiGaṇita, Baja Gaṇita, and GrahaGaṇita. Therefore when the Occidental complains of a lack of expository material he is advertising a lack of due diligence.

INDEX OF INDIC SAVANTS IN THE COMPUTATIONAL SCIENCES FROM ANTIQUITY TO 1900 CE

Nr	TABLE 1 NAMES OF INDIC SAVANTS SORTED ALPHABETICALLY
1.	Achyuta Piṣārati (c. 1550 CE-1621 CE)
2.	Al Biruni, although not from India, he spent a good part of his life in the subcontinent and made himself familiar with a vast number of subjects of relevance to the life of the Indic during his era.
3.	Allanārya Sūri, wrote commentary on Sūrya Siddhānta in Telugu, in Government Oriental Manuscripts Library, Chennai
4.	Amaredhya, son of Gosvamin, author of Kārika of SS
5.	Āpastamba, author of Sulva Sūtra, circa 2000 BCE
6.	Āryabhaţa (476 CE - 550 CE.) or 2764 BCE (appears implausible) but currently accepted date of 476 CE is highly improbable

[263] *As I completed the book, I was made aware of a collection of essays on Ancient Indian Mathematics ed. By K. V. Krishnamurthy, Chairman of ISERVE, Hyderabad, India, 2010, on the occasion of the international Congress of Mathematics*

7.	Āryabhaţa A1a (author of Āryabhaţa Siddhānta)?
8.	Āryabhaţa, A1b (author of Āryabhaţīya of Kusumapura) Born in Asmāka , A1b = or not=A1a
9.	Āryabhaţa II (author of Mahāsiddhānta)
10.	AsuraMaya or Māyāsura, apocryphal (?) author of Sūrya Siddhānta
11.	Bakṣālī Manuscript
12.	Baudhāyana (2000 BCE)
13.	Bhadrabāhu (fl. seventh, eighth, or ninth century CE) wrote Bhadrabāhu Sahiti. A Jaina Sage at Rajagrha during the reign of Senajit. Probably the same Bhadrabāhu who led the Jainas to Shrāvana Belgola in Karnataka.
14.	Bhakti Siddhānta Sarasvati Thakura (1874- 1936), author of the Grahagranitādyaya commentary on Siddhānta Siromani.
15.	Bhartṛhari, considered to be the father of semantics
16.	Melpathur Nārāyana Bhattathiri
17.	Bhāskara (fl 629 CE) resident of Vallabhi country. Astronomer familiar with Gujarat and Asmāka (in the upper Godāvari river valley). Bhāskara was one of the foremost followers of Āryabhaţa.
18.	Bhāskara II (1114-c. 1185, Bhāskarāchārya son of Maheshwara)
19.	Bhatta Utpala of Kashmir (fl. 966-969 CE) wrote commentary on Sūrya Siddhānta. He wrote a large number of commentaries on Varāhamihīra and others as well as authored independent treatises. Three of his commentaries have verses at the end indicating the dates on which they were composed.
20.	King Bhoja, author of Rajamrganka, coronation during 646 CE
21.	Bhishma Pitamaha, author of Paitamaha Siddhānta?, Paitamaha Siddhānta is incorporated in Vishnu Dharmottara Purāṇa, and not available elsewhere
22.	Bhutivesnu son of Devaraja, circa 12th century CE? , commentary on AB
23.	Bhudara (1572 CE) wrote commentary on Sūrya Siddhānta
24.	Brahma (author of Brahma Siddhānta), same as Brahmagupta?
25.	Brahmadeva son of Chandrabuddha 1092 CE
26.	Brahmagupta (c. 598 to 670 CE) , son of Jisnugupta , author of Brahma Sphuta Siddhānta, translated into Arabic @ 750 CE
27.	Brihaddeshi
28.	Changadeva (1205)
29.	Chandra prajnāpati, 5th century BCE , title of Jaina text
30.	Chakradhāra, 1550-1650, (Godavari), Yantra-chintamani.
31.	Chandeshvara. 12th century
32.	Chandraśekhara Simha or Chandraśekhara Sāmanta, 1835 CE, the last of the traditional astronomers of India
33.	Chintamani Dikṣita , 1736-1811,Golananda (1800) Misc.
34.	Damodara, son of Parameṣvara and guru of Nīlakaṇţa Somasutvan (aka Somayājī) also wrote Bhatattulya (1470 CE?)
35.	Dasaballa (son of Vairochana) 1055 CE
36.	Deva (Deva Āchārya) , wrote Karana Ratna

37.	Dīrghatamas, prolific composer of Vedic mandalas , makes the first mention of wheel of heaven of 360° divided into 12 equal parts
38.	Divakara. 1606 CE. father of Narasimha, author of Prauda Manorama, commentary on Kesava's Jātaka Paddhati
39.	Garga
40.	Ganesha Daivajna I (1505 CE son of Lakshmi and Kesava))
41.	Ganesha Daivajna II (great grandson of Ganesha Daivajna I(1600 CE)
42.	Gangādhara
43.	Gangesha Upadhyaya ·
44.	Ghatigopa
45.	Govinda Bhatta
46.	Govindaswami (c. 800-850) obtained more accurate Sine tables
47.	Halayudha (fl. 975)
48.	Haridatta (circa 850 CE) wrote Grahachara Nibhandana
49.	Hema, 15th cent. , (Gujarat), Kasa-yantra, Cylindrical Sundial.
50.	Hemachandra Sūri (b. 1089)
51.	Hemchandra
52.	Jaganath Pandit (fl. 1700)
53.	Jagannatha Samrat ·
54.	Jaisimha or Jaisingh II(1686- 1843 CE)
55.	Jayadeva (1000 CE)
56.	Jnānarāja fl1425 or 1503 CE
57.	Jyesthadeva of KERALA (circa 1500 CE?) author of Yukti bhāṣa
58.	Kakalaka Bhatti (1530 Śaka) wrote Siddhānta Tattva viveka
59.	Kamalakara (1616) alt.1610 CE, son of Narasimha (belongs to Daivajna family tree
60.	Kātyāyana , Author of Sulva Sūtras
61.	Kesava Daivajna (1496 – 1507 CE), son of Kamalakara of the Kausika Gotra, and the pupil of Vaidyanatha, residing at Nandigrama. His sons were Ananta (fl.1534 CE), Ganesha (b.1507 CE) and Rama (
62.	Kotikalapudi Kodandarama (1807-1893) of the Telugu country alternate (1854 CE) son of Venkateshwara Yajwan
63.	Kṛṣṇa Daivajna
64.	Krisnadesa
65.	Kumarajīva, (344 CE - 413 CE) son of a Indian Brāhmaṇa and a Kuchean princess translated a number of texts including the Vedāngas and transmitted Astronomical knowledge to China
66.	Lagadha, author of Vedāńga Jyotiṣa (1300 CE – 1861 CE)
67.	Lakshmidasa , son of Vachaspati Misra
68.	Lakshmidasa Daivajna
69.	Lalla or Lallacharya son of Bhatta Trivikrama, (ca. 638 to 768 CE). We do not know the exact date of his birth.
70.	Latadeva , pupil of Āryabhaṭa lb

71.	Lokavibhaga (Jaina text)
72.	Mādhava (son of ViruPakṣa of the Telugu country)
73.	Mādhava of Saṇgamagrāma in Kerala (1340 to 1425 CE) laid the foundations of Calculus, including series expansions for a number of trig functions. Is regarded by common convention as the founder of the Kerala School of Astronomy
74.	Mahādevan (son of Bandhuka)
75.	Mahādevan, wrote Venvaroham
76.	Mahādevan son of Parasurāma
77.	Mahāraja Sawai Jai Singh, 1688-1743,Yantra-prakara,Yantra-raja-racana, Misc., Astrolabe
78.	Mahāvira (Mahāvirāchārya) (850 CE)
79.	Mahāvira , founder of Jainism, author of Sūrya ā(?) and
80.	Mahāvira of the Digambara sect
81.	Mahendra Sūri (1349 CE), pupil of Madana Sūri, wrote Yantraraja, a treatise on the Astrolabe in Sanskrit.
82.	Malayagiri, Jain Monk from Gujarat , likely author of Sūrya
83.	Malikārjuna Sūri, 1178 CE, name suggest Telugu country, wrote 2 commentaries in Telugu as well as in Sanskrit
84.	Mānava, author of Sulva Sūtra
85.	Manjula (930 CE)
86.	Mathukumalli V. Subbarao ·
87.	Melpathur Nārāyaṇa Bhattathiri ·
88.	Munishvara · (17th century) author of
89.	Nagesh Daivajna (son of Shiva Daivajnya) (1619 CE)
90.	Narasimha Daivajna (son of Kṛṣṇa Daivajna) 1586 CE
91.	Nārāyaṇa Pandit (fl. 1350)
92.	Nārāyaṇa (c. 1500-1575)
93.	Nārāyaṇa Bhatathri
94.	Ayana Sukhopadhyaya(1730) translated Al Tūsi's Arabic Recension of the spherics by Theodosius of Bithunia
95.	Nīlakaṇṭa Somayājī or Nīlakaṇṭa Somasutvan (1443 CE to 1543 CE) of Kelallur, son of Jatavedas, Bhatta, following the Ashvalāyana Sūtra of the RV wrote Āryabhatīyabhāsya, 1977 (Available in Library of Congress) Trivandrum series. Pupil of Parameswara's son, Damodara, advocate of Drg Gaṇita system. Proposed a partial Heliocentric system, where he asserted that the inferior planets (Venus and Mercury) revolved around the Sun
96.	Nisanku - son of Venkata Kṛṣṇa Sastri (source, sourcebook KVS)
97.	Nityananda (circa 1639)court Astronomer of Shah Jahan (1627-1658) Author of Siddhānta Singhu, a Samskṛta translation of Zij I Shah Jahani compiled by Fariduddin Munajim

98.	Padmanabha son of Narmada (same as Parameșvara?) 1400 CE, author of Yantra-Kiranavali developed an instrument ,Astrolabe, Dhruva-Brāhmaṇa- yantra,
99.	Panduranga swami
100.	Pāṇini
101.	Parameșvara (1360-1455 CE) alt.1380 — 1460 CE, a Namputiri of Vataserri in Kerala, founder of Drg Gaṇita school
102.	Parāsara circa 3000 BCE
103.	Pavaluri Mallana
104.	Patodi
105.	Pingala
106.	Prabhākara (pupil of Āryabhaţa I, 525 CE?
107.	Prashastidhara (fl. 958)
108.	Chaturveda Prthudakasvami (fl. 850), commentary on Brahma Sphhuta Siddhānta , "Just as grammarians employ fictitious entities, such as Prakrti, pratyaya, Agama, lopa, vikāra, etc to decide on the established real word forms, and just as Vaidyas employ tubers to demonstrate surgery, one has to understand and feel the content that it is in the same way that the astronomers postulate measures of the earth etc., and models of motion of the planets in Manda and Śīghra-pratimandalas for the sake of accurate predictions " In other words, a Model is a representation of reality but not reality itself. Do not fall in love with your model, is the constant refrain of Indic astronomers.
109.	Putumana Somayājī (c. 1660-1740)
110.	Rajagopal
111.	Rama Daivajna , son of Madhusūdhana Daivajna
112.	Ramakṛṣṇa Aradhya
113.	Ranganatha son of Narasimha Daivajna (1643 CE). commentary on Sūrya Siddhānta
114.	Sāmanta Chandraṡekhara Simha (see also Chandraṡekhara Sinha)
115.	Ṡakalya, 821 CE
116.	Sankaranārāyana (869 CE) wrote Sankaranārāyanīyam
117.	Sankara Variyar (1500 — 1600 CE) pupil of Jyeșţhadeva
118.	Sankara Varman (fl. 1800)
119.	Satananda, end of 11th century, wrote calendrical work Bhaswāti, based on Varāhamihīra's Sūrya- Siddhānta.
120.	Somaswara circa 11 century CE
121.	Sphujidvaja
122.	Sridhara (fl. 900)
123.	Sridharāchārya
124.	Srinivasa Rāmānujan (1900)
125.	Sripati (son of Nagadeva, 999 CE)
126.	Sumati of Nepal (800 CE), wrote 2 works called Sumati tantra and Sumati-karana
127.	Sūryadeva Yajwan (1191 CE of Gangaikonda Cholapuram in South India) 61 km from Thanjavur wrote commentary on the Āryabhattiya

128.	Tamma Yajwa, 1599 CE, commentary on Sūrya Siddhānta, son of Malla Yajwa and Venkatamba, wrote commentary (in Telugu?)
129.	Trikkantiyur -
130.	Udaya Divakaran (1073 CE), commentator of the Laghu Bhāskariya
131.	Umāsvāti (fl. 150 BCE.)
132.	Vararuchi. There are at least 3 Varuruchi's mentioned. One of them was an astronomer and a contemporary of Varāhamihīra
133.	Varāhamihīra (son of Ādityadāsa), (c. 505-c. 558)
134.	Vaṡiṣţa
135.	Vateṣvara (fl 882 - 904 CE), author of Vateṣvara Siddhānta, follows Ārya Pakṣa and Saura Pakṣa
136.	Vijayanandi
137.	Viddana 14TH Century
138.	Virasena ·
139.	Virasena Acharya
140.	Viru Pakṣa Sūri of the Telugu country
141.	Vishnu Daivajna (son of Divakara Daivajnya) same as Visvanatha?
142.	Visvanatha Daivajna (son of Divakara Daivajna) 1578 CE
143.	Vriddha Garga
144.	Yājnavalkya (author of Ṡatapatha Brāhmaṇa and Brihat Āranyaka U) 3000 BCE. The BU constitutes in fact, the last 6 Chapters of the Ṡatapatha Brāhmaṇa
145.	Yallaiya (1482 CE of Skandasomeswara of the Telugu country)
146.	Yāska
147.	Yatavrisham Acharya
148.	Yativṛṣabha (Jain monk, 6th century)
149.	Yavaneṡvara (see Sphujidvaja) ca. 200 BCE

TABLE 2 INDIC SAVANTS SORTED BY DATE DURING WHICH THEY FLOURISHED.

Note that there are few centuries in which the Indic savant is absent. This is contrary to the widespread belief in the Occident, that after the first few centuries in which they allegedly imbibed the knowledge from Greece, there was very few new developments in India. This makes a mockery of the Hegelian Hypothesis and of David Pingree's oft stated opinion that India had no tradition of astronomy.

<4000 BCE	Dīrghatamas, the blind and prolific composer of Vedic mandalas , makes the first mention of wheel of heaven of 360° divided into 12 equal parts
3200 BCE	Sage Parāsara, had surprisingly a very mature view of time considering his antiquity
3100 BCE	Bhishma Pitamaha, author of Paitamaha Siddhānta?, Paitamaha Siddhānta is incorporated in Vishnu Dharmottara Purāṇa, and not available elsewhere
3000 BCE	Yājnavalkya (author of Ṡatapatha Brāhmaṇa and Brihat Āranyaka U) 3000 BCE
2500 BCE	Vṛddha Garga
2000 BCE	Āpastamba, author of Sulva Sūtra, circa 2000 BCE

2000 BCE	Baudhāyana (2000 BCE), author of Sulva Sūtra
2000 BCE	Kātyāyana , Author of Sulva Sūtras
2000 BCE	Mānava, author of Sulva Sūtras
2000-350BCE	Pāṇịni, possible developer of semantic zero and the DPV system
1350 BCE	AsuraMāya or Māyāsura, apocryphal author of Sūrya Siddhānta
1350 BCE	Lagadha, author of Vedāńga Jyotiṣa (1300 BCE - 1861 BCE)
1000 BCE	Yāska, author of Nirukta, to prevent loss of knowledge over time, developed the discipline of Etymology
700 BCE	Mahāvīra , founder of Jainism, author of Sūrya Prajnāpati and
460 BCE	Chandra prajnāpati, 5th century BCE, author
200 BCE	Sphujidvaja
200 BCE	Yavaneṡvara, see Sphujidvaja) ca. 200 BCE
150 BCE	Umāsvāti (fl. 150 BCE.)
100 BCE	Bhartṛhari, considered to be the father of semantics
55 BCE	Varuruchi
0	Bakṣāli Manuscript
499 CE	Āryabhaţa (476 CE - 550 CE. Appears too late) or 2764 BCE(appears implausible), Most probable time for AB is 500 BCE- 600 BCE
525	Prabhākara (pupil of Āryabhaţa I, 525 CE?
540	Varāhamihīra (son of Ādityadāsa), (c. 505-c. 558) could be as early as 55 BCE
550	Yativṛṣabha (Jain monk, 6th century). This is the conventional date
640	Bhāskara I(? 629 CE) resident of Vallabhi country. Astronomer familiar with Gujarat and Asmāka (on the upper Godāvari). Bhāskara was one of the foremost followers of Āryabhaţa
640	Brahmagupta (c. 598-c. 670) , son of Jisnugupta , author of Brahma Sphuta Siddhānta, translated into Arabic @ 750 CE
646	King Bhoja, author of Rajamrganka, coronation during 646 CE
650	Brahma (author of Brahma Siddhānta), same as Brahmagupta?
700	Lalla or Lallacharya son of Bhatta Trivikrama, authored SDV (see abbreviations Appendix F).
750	Bhadrabāhu (? seventh, eighth, ninth century CE) wrote Bhadrabāhu Sahitį. A Jaina Sage at Rajagrha during the reign of Senajit. Probably the same Bhadrabāhu who led the Jainas to Shravana Belgola in Karnataka.
800	Sumati of Nepal (800 CE), wrote 2 works called Sumati tantra and Sumati-karana
821	Ṡakalya, 821 CE
850	Chaturveda Prthudakasvami (fl. 850), commentary on Brahma Sphhuta Siddhānta , "Just as Grammarians employ fictitious entities, such as Prakrti, pratyaya, Agama, lopa, vikāra, etc to decide on the established real word forms, and just as Vaidyas employ tubers to demonstrate surgery, one has to understand and feel the content that it is in the same way that the astronomers postulate measures of the earth etc., and models of motion of planets.
850	Govindaswami (c. 800-850) obtained more accurate Sine tables

850	Haridatta (circa 850 CE) wrote Grahachara Nibhandana
850	Mahāvira (Mahāvīrāchārya) (850 CE)
869	Sankaranārāyana (869 CE) wrote Sankaranārāyanīyam
882	Vateṣvara (fl 882 - 904 CE), author of Vateṣvara Siddhānta, follows Ārya Pakṣa and Saura Pakṣa
900	Sridhara (fl. 900. 870-930)
930	Manjula (930 CE)
958	Prashastidhara (fl. 958)
966	Bhatta Utpala of Kashmir (? 966-969 CE) wrote commentary on Sūrya Siddhānta. Wrote s large number of commentaries on Varāhamihīra and others as well as independent treatises on his own. Three of his commentaries have verses at the end indicating the dates on which they were composed.
975	Halayudha (fl. 975)
999	Sripati (son of Nagadeva, 999 CE)
1000	Al Biruni, although not from India, spent a good part of his life in the subcontinent and made himself familiar with a vast number of subjects of relevance to the life of the Indic during his era.
1000	Jayadeva (1000 CE)
1050	Somaswara circa 11 century CE
1055	Dasaballa (son of Vairochana) 1055 CE
1070	Udaya divakaran (1073 CE), commentator of the Laghu Bhaskarīya
1089	Hemachandra Sūri (b. 1089)
1092	Brahmadeva son of Chandrabuddha 1092 ce
1099	Satananda, end of 11th century, wrote calendrical work Bhaswāti, based on Varāhamihīra's Sūrya- Siddhānta. References of all astronomical measurements are given from his birthplace Puri in Orissa
1150	Bhāskara II (1114-c. 1185, Bhāskarāchārya son of Maheshwara)
1150	Bhutivesnu son of Devaraja, circa 12th century CE? commentary on AB
1175	Malikārjuna Sūri , 1178 CE, name suggest Telugu country, wrote 2 commentaries in Telugu as well as in Sanskrit
1191	Sūryadeva Yajwan (1191 CE of Gangaikonda in South India (likely to be in Andhra country)
1205	Changadeva (1205)
1349	Mahendra Sūri (1349 CE), pupil of Madana Sūri, wrote Yantraraja, a treatise on the Astrolabe in Sanskrit. Probably hailed from Andhra Country, belonging to the illustrious Sūri Kula.
1350	Nārāyaṇa Pandita (fl. 1350), son of Narasimha and author of Gaṇitakaumudi (CESS, 3, 156)
1380	Mādhava of Saṇgamagrāma in Kerala (1340 to 1425 CE) laid the foundations of Calculus , including series expansions for a number of trig functions, the earliest known Āchārya of the Kerala school.
1400	Padmanabha son of Narmada (same as Parameswara?) 1400 CE, author of

	Yantra-Kiranavali developed an instrument , Astrolabe, Dhruva-Brāhmaṇa-yantra,
1400	Parameṣvara (1360-1455 CE) alt.1380 - 1460 CE, a Namputiri of Vataserri in Kerala, founder of Drg Gaṇita school
1417	referred to as son of Padmanabha (1417 CE) are they one and the same
1425	Jnānarāja fl1425 or 1503 CE
1450	Rama Daivajna , son of Madhusūdhana Daivajna
1450	Hema, 15th cent. (Gujarat), Kasa-yantra, Cylindrical Sundial.
1470	Damodara, son of Parameswara and guru of Nīlakaṇţa Somasutvan also wrote Bhatattulya (1470 CE)
1480	Nīlakaṇţa Somayājī or Nīlakaṇţa Somasutvan (1443 CE to 1543 CE) of Kelallur, son of Jatavedas, Bhatta, following the Ashvalāyana Sūtra of the RV wrote Āryabhaţīyabhāṡya, 1977 (Available in Library of Congress) Trivandrum series. Pupil of Parameswara's son, Damodara, advocate of Drg Gaṇita system. Proposed a partial Heliocentric system, where he asserted that the inferior planets (Venus and Mercury) revolved around the Sun
1482	Yallaiya (1482 CE of Skandasomeswara of the Telugu country), wrote a more elaborate commentary based on the work of Sūryadeva Yajwan
1500	Jyesthadeva of Kerala (circa 1500 CE) author of Yukti bhāṣa
1500	Kesava Daivajna (1496 - 1507 CE), son of Kamalakara of the Kausika Gotra, and the pupil of Vaidyanatha, residing at Nandigrama. His sons were Ananta (fl.1534 CE), Ganesha (b.1507 CE) and Rama.
1500	The Daivajna Family - The extended family of astronomers of India, contemporaneous with the later Kerala Astronomers
1505	Ganesha Daivajna I (1505 CE son of Lakshmi and Kesava))
1550	Acyuta Pisārati (c. 1550 CE-1621 CE**)**
1550	Sankara Variyar (1500 - 1600 CE) pupil of Jyeşţhadeva
1550	Nārāyaṇa (c. 1500-1575).Commentator of Lilāvati?). There is a lot of circumstantial evidence that the Jesuits learned the trade of Indic Jyotiṣa from either Nārāyaṇa or his brother (?) Sankara Variyār, having convinced the King of Travancore, of their desire to learn the same.
1559	Nārāyaṇa Bhattathiri (1559–1632)
1572	Bhudara (1572 CE) wrote commentary on Sūrya Siddhānta
1578	Visvanātha Daivajna (son of Divakara Daivajna) 1578 CE
1586	Narasimha Daivajna (son of Kṛṣṇa Daivajna) 1586 CE
1599	Tamma Yajwa, 1599 CE, commentary on Sūrya Siddhānta, son of Malla Yajwa and Venkatamba, wrote commentary (in Telugu?)
1600	Chakradhāra, 1550-1650, (Godavari), Yantra-chintamani, Quadrant
1600	Ganesha Daivajna II (great grandson of Ganesha Daivajna I1(1600 CE)
1600	Kakalaka Bhatti (1530 CE) wrote Siddhānta Tattva viveka
1606	Divakara. 1606 CE. father of Narasimha, author of Prauda Manorama, commentary on Kesava's Jataka Paddhati

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Comment [5]:

1616	Kamalakara (1616) alt.1610 CE, son of Narasimha (belongs to Daivajna family tree
1619	Nagesh Daivajna (son of Ṣiva Daivajna) (1619 CE)
1639	Nityananda (circa 1639)court Astronomer of Shah Jahan (1627-1658) Siddhānta Singhu Skrt translation of Zij I Shah Jahani compiled by Fariduddin Munajim
1643	Ranganatha son of Narasimha Daivajna (1643 CE) commentary on Sūrya Siddhānta
1650	Munishvara · (17th century) author of the Siddhānta Sarva Bhauma
1700	Jaganath Pandit (fl. 1700) was the astronomer attached to the court of Mahāraja Jai Singh (the builder of the Jantar Mantars). It is astonishing that the first translation of Euclid into Sanskrit was done By Jaganatha in the late 18th or early 19th Century.
1700	Putumana Somayājī (c. 1660-1740). Kerala School. Wrote Karana Paddhati (early 18th century) a compendium of results available till that date.
1720	Mahāraja Sawai Jai Singh (Jaisimha) , 1688-1743,Yantra-prakara,Yantra-raja-racana Misc., Astrolabe
1730	Ayana Sukhopadhyaya(1730) translated Al Tūsi's Arabic Recension of the spherics by Theodosius of Bithunia
1756	Krisnadāsa
1791	Chintamani Dikṣita , 1736-1811,Golananda (1791-1800)
1800	Jaisimha or Jaisingh II(1786- 1843 CE)
1800	Sankara Varman (fl. 1800)
1833	Nilambara Jha of Mithila, Commentary on Siddhānta Ṣiromani by Bhāskara II CESS 3;193-195.The text on Plane and spherical trigonometry, contains the following adhyāyas; Jyotpatti, trikonamiti, golīyatrekhā Gaṇita, chāpīyatrikoṇagaṇita, praŝnāh
1830	Sāmanta Chandraŝekhara Simha (see also Chandraŝekhara Sinha)
1850	Ghatigopa, Commentary on Ārya bhattiya of Āryabhaţa
1850	Kotikalapudi Kodandarāma (1807-1893) of the Telugu country alternate (1854 CE) son of Venkateshwara Yajwan
1900	Bhaktisiddhānta Sarasvati Thakura (1874- 1936), author of the Graha Ganitādyaya commentary on Siddhānta Siromani,
1900	Srinivasa Ramanujan
1900	Sridharāchārya

BIOGRAPHIES OF A FEW OF THE FAMOUS INDIAN MATHEMATICIAN-ASTRONOMERS

1. ***DĪRGHATAMAS (TERMINUS ANTE QUEM 4000 BCE)* ,दीर्घतमस, *DIRGHATAMAS* AND THE ZODIAC WHEEL OF THE HEAVENS 360 DEGREES**

One of the most important mathematical contributions of ancient times is the idea of a zodiac or wheel of Heaven of 360 degrees. This discovery is usually attributed by western scholars to the Babylonians of around 400 BCE.[264] However, the symbolism of 360 relative to a wheel of Heaven is common in Vedic literature back to the RV itself, the oldest Hindu text, usually dated from 1500 BCE back to as early as 5000 BCE. 360 is a very significant number for the Vedic mind. Therefore, along with the decimal system and the discovery of zero, the 360 degree zodiac should be credited to India. In addition, the twelve signs of the zodiac are generally also credited to the Babylonians and said by modern scholars to have come to India by a Greek influence after the time of Alexander (300 BCE). However, the Vedic 360 wheel of Heaven is also said to be divided into twelve parts. Whether these twelve parts are identical with those of the western signs of the zodiac, is not clear from the Vedas themselves, but it is clear that the idea that the 360 part zodiac could be divided into twelve is also there.

Relative to the Nakṣatra system, this 360 degree wheel of Heaven is associated with Nakṣatra positions relative to solstice and equinox points that date well before 2000 BCE.

In short, the Vedic knowledge of the 360 degree zodiac is additional proof of the sophistication and antiquity of Vedic culture, that it had reached a high degree of mathematical and astronomical knowledge before 2000 BCE that is usually only attributed to the Babylonians after 400 BCE.

The number 360 and its related numbers like 12, 24, 36, 48, 60, 72, 108, 432, and 720 occur commonly in Vedic symbolism. It is in the hymns of the great Riṣi Dīrghatamas (RV I.140 – 164) that we have the clearest such references.

Dīrghatamas is one of the most famous R.V. Riṣis, who happened to be born blind. He was the reputed purohit or chief priest of King Bharata (Aitareya Brāhmaṇa VIII.23), one of the earliest kings of the land, from which India as Bharata (the traditional name of the country) was named.

Dīrghatamas was one of the Angirasa Riṣis, the oldest of the Riṣi families, and regarded as brother to the Riṣi Bharadvaja, who is the seer of the sixth book of the RV. Dīrghatamas is also the chief predecessor of the Gotama family of Riṣis that includes Kakṣivan, Gotama, Nodhas and Vāmadeva (seer of the fourth book of the RV), who along with Dīrghatamas account for almost 150 of the 1000 hymns of the RV. His own hymns occur frequently in many Vedic texts and verses from them occur commonly in the Upanishads as well. A number of famous sayings originate from the verses of Dīrghatamas.

Another one bites the dust The first time the phrase “bites the dust” appears is in the RV (1.158.4-5) where the poet Dīrghatamas has a prayer to the divine doctors and says ‘may the turning of the days not tire me, may the fires not burn me, may I not bite the earth, may the waters not swallow me’. There are disputes on what “bites the dirt” means in `’s commentary in the 14th century- which means the phrase had gone out of style in India at this time as most people began to be cremated instead of buried. But we can see Dīrghatamas is using it as a prayer from death- such as don’t let me die and be burned, or die and be buried, or die and be thrown in the river. [Dust and dirt are often used interchangeably in old translations] That said, the meaning of bites the dust would be – to die and be buried in the earth. It can also be used figuratively as something that has failed (or is in a state where it is as if it was dead and buried). Another one bites the dust is another one dead and buried- or another one finished. http://en.wikipedia.org/w/index.php?title=Dīrghatamas&action=edit.[265]

2. YĀJNAVALKYA (TERMINUS ANTE QUEM OF 2000 BCE)

Sage Yājnavalkya (याज्ञवल्क्य) of Mithila advanced a 95-year cycle to synchronize the motions of the sun

[264] Pandit Vāmadeva Śastry “The Zodiac of 360 Degrees: A Vedic Discovery The Hymns of Dīrghatamas in the RV “
[265] 1. MBH, book1, Adi Parva, CIV, 2. RV , suktas 140 to 164

and the moon. He is also credited with the authorship of the Ṡatapatha Brāhmaṇa (which includes the Bṛhadāranyaka, बृहदारण्यक उपनिषद् Brihat – Āranyaka Upanishad), in which the references to the motions of the Sun and the Moon are found. A date of 3200 BC is sometimes suggested by the astronomical evidence within the Ṡatapatha Brāhmaṇa, while some Western scholars dispute not only the chronology but also his historicity. But their main motivation in doing so seems to stem from a congenital aversion to concede that India has unquestionably a civilization of a very high antiquity. **Yājnavalkya** is also a major figure in the Upanishads. His deep philosophical teachings in the Bṛhat Āranyaka, and the apophatic teaching of 'neti neti' etc. is found to be startlingly similar to the Buddhist Anatta doctrine and to modern science. I am compelled to note that to decipher that there exists such a cycle presupposes not only observations but many insights into the quantitative aspects of Astronomy. The Metonic cycle wrongly associated with the name of Meton has its origins in India and could have been invented independently later by the Babylonians. Unlike the Occidental we do not feel compelled to make the categorical statement that Babylon borrowed the idea from the ancient Indics, based simply on circumstantial evidence, but it appears to be highly probable.

Yājnavalkya married two women. One was Maitreyi and the other Kātyayāni. Of the two, Maitreyi was a Brahmavadini (one who is interested in the knowledge of Brahman and more inclined towards the pursuit of higher knowledge). When Yājnavalkya wished to divide his property between the two wives before starting for the fourth Ashrama of his life (sanyasa), Maitreyi asked whether she could become immortal through wealth. Yājnavalkya replied that there was no hope of immortality through wealth and that she would only become one among the many who were well-to-do on earth. On hearing this, Maitreyi requested Yājnavalkya to teach her what he regarded as the higher knowledge. Then Yājnavalkya elaborately described to her the sole greatness of the Absolute Self, the nature of its existence, the way of attaining infinite knowledge and immortality, etc. This immortal conversation between Yājnavalkya and Maitreyi is recorded in the Bṛhadāranyaka Upanishad. The Upanishad is one of the older, primary (mukhya) Upanishads commented upon by Sankara.

"All things are dear, not for their sake, but for the sake of the Self. This Self alone exists everywhere. It cannot be understood or known, for It alone is the One that Understands and Knows. Its nature cannot be said to be positively as such. It is realized through endless denials as 'not this, not this'. The Self is self-luminous, indestructible, and unthinkable".

The central theme of the discourse is the nature of Brahman in the Vedantic (and subsequently Yogic) forms of Hinduism. Brahman is the signifying name given to the concept of the unchanging, infinite, immanent, and transcendent reality that is the Divine Ground of all being in this universe. Sanyāsa symbolizes the conception of the mystic life in Hinduism where a person is now integrated into the spiritual world after wholly giving up material life. Thus, it is the consensus that the Wisdom of Yājnavalkya is revealed to a greater extent in the Bṛhadāranyaka Upanishad where he imparts his teachings to his wife Maitreyi and King Janaka.

He also participates in a competition arranged by King Janaka of Mithila (Mithila was a kingdom in ancient India) to select the great Brahma Jnāni (one who knows Brahman) and wins after defeating several learned scholars and sages. This forms a beautiful chapter filled with lot of philosophical and mystical question-answers in the Bṛhadāranyaka Upanishad. In the end, Yājnavalkya took Vida Sanyasa (renunciation after the attainment of the knowledge of Brahman) and retired to the forest. The Bṛhadāranyaka is the prime Upanishad among the many Upanishads written in ancient India, known very widely for its profound philosophical statements. In Ancient India, Janaka was the King of the Mithila Kingdom.

Yājnavalkya was one of the greatest sages ever known. His precepts as contained in the Upanishads (The Bṛhadāranyaka Upanishad) stand foremost as the crest-jewel of the highest teachings on knowledge of Brahman. His knowledge of the skies and the periodicities of the planets was far ahead of his time. It is possible that reading his works may give us clues as to the identity of the person who conceptualized the Śūnya.

3. PARĀSARA AND TIME (3000 BCE)

In the Eleventh chapter of the Bhagavad Gita, Ṣhri Kṛṣṇa makes some very revealing comments on the nature of time. In the 33rd text, He tells us: "Time I am, the great destroyer of the worlds." It is very significant that Shree Kṛṣṇa refers to time in the first person; He says "Time ' I ' am." In the ninth chapter He makes reference to the material nature in the possessive case saying "This material nature, which is one of my energies, is working under my direction." But with reference to Time, Shree Kṛṣṇa speaks in the first person.

Thus Time enjoys a very special place in the scheme of things within the creation; Time is the will of God as manifested as a chronology. It is experienced and perceived in various ways, typically invoking fear and sadness.

Time's role as a beginning and end is generally well understood, but there are other, less understood aspects of Time which have been pointed out in the 11th chapter of Gita (Texts 33 and 34): " Conquer your enemies and enjoy a flourishing kingdom. They are already put to death by My arrangement, Oh Savyāsachi, and you can be but an instrument in the fight. Drona, Bhishma, Jayadratha, Karna, and the other great warriors

Parāsara belongs to a very early era in the historical narrative of the ancient Riṣis of India. He is reputed to be the father of Veda Vyāsa and the grandson of Va**ś**iṣţa. He is credited with being one of the first astronomers of India. His probable date is prior to that of Veda Vyāsa and can be tentatively dated to 3200 BCE. Other Astronomers of the Vedic Era; Asita, Devala, Atharva muni.

4. THE SULVASŪTRAS – ĀPASTAMBA, KĀTYĀYANA, BAUDHĀYANA, MĀNAVA (3RD TO 2ND MILENNIUM BCE)

In many of the ancient countries and India was no exception, the development of mathematics was necessitated on account of religious practices and observances. These required an accurate calculation of the times of certain festivals and of the times auspicious for the performance of certain sacrifices or acts of worship. They also required a correct knowledge of the times of rising and setting of the sun and the moon, and of the occurrences of solar and lunar eclipses. All these meant a good knowledge of astronomy which in turn meant an accurate knowledge of arithmetic, plane and spherical geometry and trigonometry, and possibly also the construction of simple astronomical instruments.
The discovery of the Sulva Sutra by G Thibaut in 1874[266] and the subsequent spread of this piece of evidence of Ancient India's prowess in Geometry did not lead to the logical inference that India had priority in Geometry over the Babylonians and the Greeks. This despite the fact that even with their Jaundiced view of anything Indian, they had to admit that the Sulvas which were a part of the 6

[266] *Thibaut G., On the Sulva sutras, JASB, 9, 1874*
Thibaut G., SulvaSūtras of Baudhāyana, The Pandit, 9,1874 and 10,1875

Vedāńgas and in particular were a part of the Kalpa Ṣastra, could not have a date lower than 1000 - 800 BCE. But, Thibaut himself says in 1884, nine years after he reported on the discovery of the Sulvas that; "There prevails no longer any doubt that the system exhibited in works like the Sūrya Siddhānta and Laghu Ārybhaţīya is an adaptation of Greek Science".

Whoa, hold your horses here, how did he reach this conclusion when he knows full well that India possessed not only geometry but computational geometry long before the Greeks and even the Babylonians. Remember that the Chaldeans who were the first computational astronomers in Babylon, could not have produced the complex science that is presently under way at that epoch prior to 500 BCE. I regard Thibaut and to a certain extent Cantor[267] to be dishonest for letting us believe that India could not have been the progenitor of the science that was available in the Sūrya Siddhānta. The Sūrya Siddhānta did not need any new Geometry than was available in the Sulva Sūtras and it would have dawned on Thibaut and Cantor that the Ancient Indic did indeed have an embarrass de choix when it came to techniques to use in the calculation of the mean and true anomaly. In fact there does not appear to be a single algebraic equation in the Almagest and yet they took the position that the ancient Indic had plagiarized without attribution and chose to take a stand that had no basis or relation to the truth. It was quite impossible for the Indics to plagiarize, for the simple reason that the Yavanas nothing to plagiarize. If this is indeed the state of ethics amongst those who should set an example, I shudder to think what the ethics were of the run of the mill Colonial civil service bureaucrats who ran India.

In the Vedic religion, every house-hold man (i.e. barring the Sanyāsis who would concentrate on meditation uninterruptedly for years) had to do certain acts of worship every day. It would be sinful if he neglected them. For purposes of worship, he would constantly maintain in his house three types of Agnis or fires sheltering them in certain altars of special design. The Agnis were called Dakṣinā Agni (दक्षुणाग्नि), Gārhapatya (गार्हपत्य) and Āhavānīya (आहवानीय). The required altars had to be constructed with great care so as to conform to certain specific shapes and areas. The altar for the Gārhapatya Agni was square in one system, and circular in another system. The altars for the Āhavānīya Agni and the Dakshinā Agni were respectively square and semi-circular. The unit of length employed was the Vyam or Vyayam which was about 96 inches. The word Puruṣa (=man) is also used for this length. The area of the altar had to be exactly one square Vyam, and the altar had to be constructed as accurately as was possible so as to conform to the rules.

While the above Agnis were to be used for the daily or routine Pujas or acts of worship, there were more elaborate sacrifices or Pujas for attaining certain cherished objects or wants. They were called Kamyagnis. An act of worship done with a specific worldly desire is an inferior form of worship spiritually, but was popular with the Kings. Congregations of sages could also do this for the well-being of the entire community. The sacrificial altars for these Kamyagnis required more complicated constructions, involving combinations of rectangles, triangles, and trapezia. The more elaborate sacrifices also required during the progress of a sacrifice the transference of the Agni to another altar either of the same shape or of a different shape, whose area bore a specific simple ratio to that of the original altar.

It will be clear that these processes require a clear knowledge of the properties of triangles, rectangles and squares, properties of similar figures, and a solution of the problem of 'squaring the circle' and its converse, 'circling the square' (i.e. to construct a square equal in area to a given Several references to

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[267] *Cantor G, Vorlesungen ´Über Gesichte Der Mathematik,1, Leipzig , 1907*

them are available in the R.V. Saṃhita. The science of the constructions of the altars takes a more specific form in the Taittiriya Saṃhita and the Taittiriya Brāhmaṇa. Mention may also be made of the provision of these altars which Rāma observes when he enters the hermitage of the sage Agasthya, and in Rāma's own hermitages both at Chitrakoot and Panchavati.

In the hereditary handing down of instructions from father to son, and from the preceptor to the disciple so characteristic of the Hindu tradition in the past, the need for setting out the instructions in a written form was only slowly felt. In this way were written the several Sulva Sūtras which were to be treated as adjuncts or appendices to the corresponding scriptural texts known as the Srauta Sūtras. The root meaning of the word Sulva is to measure, and in due course the word came to mean the rope or cord. Geometry in ancient India was for long known by the name Sulva or Rajju (=rope). The name Rekha Gaṇita is of later origin.

Only seven of the Sulva Sūtras are known at present. They are known by the names Baudhāyana, Āpastamba, Kātyāyana, Mānava, Varāha, and Vadhula after the names of the Riṣis or sages who wrote them. The Kātyāyana Sūtra belongs to the section of the Vedas called Sukla Yajurveda while all the rest belong to Kṛṣṇa Yajurveda. The Baudhāyana, Āpastamba, and Kātyāyana Sulvas are of importance from the mathematical point of view.

The conventional dating of these Sulva Sūtras have been estimated to be between 800 BCE and 500 BCE. But more work needs to be done to decipher the actual dates of the Sulva Sūtras. The author of these Sūtras also wrote other parts of the Kalpa Sūtra[268] There is no knowledge about the existence of any Sulvas prior to these seven Sūtras. It must be emphasized that the writers of the Sulva Sūtras only wrote down and codified the rules for the constructions of the altars, which were in vogue from ancient times. They were not the persons who specified and directed the rules for the constructions of the altars.

TABLE 3 A SAMPLE OF THE GEOMETRY OF THE SULVA SŪTRAS (SS)
The diagonal of a rectangle divides it into two equal parts.
The diagonals of a rectangle bisect each other and the opposite areas are equal.
The perpendicular through the vertex of an isosceles triangle on the base divides the triangle into equal halves.
A rectangle and a parallelogram on the same base and between the same parallels are equal in area.
The diagonals of a rhombus bisect each other at right angles.
The famous theorem known after the name of Pythagoras.
Properties of similar rectilinear figures.

The Sulvas explain a large number of simple geometrical constructions — constructions of squares, rectangles, parallelograms and trapezia. These and others involve the following theorems:

These cover roughly the first two books and the sixth book of Euclid. How these theorems were actually obtained is a matter for which no definite answer is available. We all know that Euclid's geometry is based upon certain axioms and postulates, and the proofs involve a strict logical application of these. The logical methods of Greek geometry are certainly not discernible in Hindu geometry. No book on

[268] See Appendix D The Vedic episteme

Hindu mathematics explains the system of axioms and postulates assumed, and this observation refutes in part, the concocted claim that Hindu mathematics is borrowed from the Greeks. At the same time, it may not be correct to conclude that the above theorems were asserted as a matter of experience and measurement. The people who could make out and solve complicated problems of arithmetic, algebra, and spherical trigonometry should be credited with some amount of logic in their work. The Sulvas are not formal mathematical treatises. They are manuals for the construction of altars and constitute rules for mensuration. The actual theories on which these rules were based are probably of even greater antiquity.

FRACTIONS

The essentially arithmetical background of the Sulva mathematics must be contrasted with the essentially geometrical background characteristic of Greek mathematics. Simple fractions and operations on them are available in the Sulvas. We meet with fractions like 3/8 (Thri Ashtama), 2/7 (DWI Saptama), 3/4 (Chaturbhagona). These are not unit fractions only, as were used in ancient Egypt, Babylonia, and China. Āpastamba gives the area of a square of side 1-1/2 Puruṣas as 2-1/4, and that of a square of side 2-1/2 as 6-1/4. If the area is 7-1/9 sq. Puruṣas, the side of the square is 2-2/3 (Baudhāyana).

SURDS

Surds of the form √2, √3 etc. are called Karanis, thus √2 is dwi-karani, √3 = trikarani,
√1/3 = triteeya karani, √1/7 = saptama karani, √18 = ashtadasa karani.

The shape of the Ashwamedhiki Vedika is an isosceles trapezium whose head, foot and altitude are respectively 24√2, 30√2, 36√2 prakramas. Its area is stated to be 1944 prakramas (sq. is to be understood).
Area=36√2 x 1/2*(24√2 + 30√2) = 1944.

This indicates knowledge of the method of finding the area of - a trapezium, and simple operations on surds.
Square root of 2
A remarkable approximation to √2 occurs in each of the three Sulvas Baudhāyana, Āpastamba and Kātyāyana, viz.

√2 = 1 + 1/3 + 1/ (3*4) - 1/ (3*4*34)

This gives √2 = 1.4142156, whereas the true value is 1.414213. The approximation is thus correct to five decimal places, and is expressed by means of simple unit fractions. The problem evidently arises in the construction of a square double a given square in area.

The Sulvas contains no clue at all as to the manner in which this remarkable approximation was arrived at. Many theories or plausible explanations have been proposed, but a heuristic explanation is given by Thibaut
Now $17^2 = 2(12)^2 + 1$ ……………………………………………………………………………. (1)
Thibaut then asks the question by how much does 17^2 need to be diminished in order for it to be equal to $2(12)^2$ (to the required number of decimal places)
Since 2 *17 * 1/34 = 1, he observes that 2 rectangular strips each of 1/34 could be cut off from the square of 17, $[17 – (1/34)]^2 \approx 2(12)^2$

17 – (1/34)/12 = $\sqrt{2}$ …………………… (2)
Again 17 – (1/34= 12 +4+1- 1/34
17 –(1/34) = 12 (1 +1/3 + 1/3*4 + … (3)
Srinivasa Iengar mentions that the Sulva Sutra knew of a higher order approximation for the

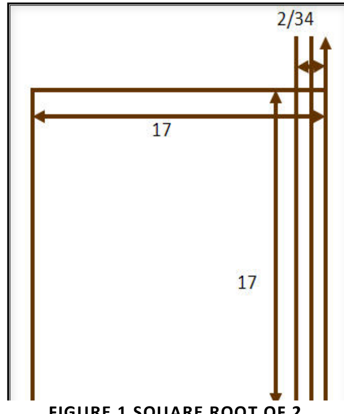


FIGURE 1 SQUARE ROOT OF 2

Square root. The following is an excerpt from his book
The fourth order approximation was known to the authors of the Sulva
Define the following
b = r/ (2a +1………………………………………… (4)
c = b (1 – b)/ (2 (a + b) ………………………… (5)
then the error ε = r – (b + c) (2a + b +c)/ 2(a + b + c)…………………(6)

Instantiating for **a =1, r = 1**, w get back to the formula given in the Āpastamba Sulva Sūtra
$\sqrt{\mathbf{2}}$ = 1 + $\mathbf{1/3}$ + $\mathbf{1/3.4}$ - $\mathbf{1/3.4.34}$
This rule gives an approximation by defect (less than the true value) while the previous one gives an excess. Rodet credits this rule to the authors of the Sulva, on the basis of geometrical constructions. Bhibutibhushan Datta feels that the approximation was obtained by the method of continued fractions, though they may have used simple examples as these. The actual proofs of the various approximations still remain a matter for research.
This approximation is applied in the Bakṣāli manuscript to the calculation of the error and consequent process of verification in a certain type of problem. That there was an error analysis, so far back in antiquity, is in itself astonishing to us and it is probably unique for that period in recorded history. If the number of terms of an arithmetic progression whose first term is **a**, common difference is **d**, whose number of terms is **t** , then the sum is given in the Bakṣāli Ms as

S = $\{\frac{(t-1)d}{2} + a\}$ **t**

It is also interesting to note that three approximations of √2 are given.

√2	=	7/5
√2	=	17/12
√2	=	577/408

Now the continued fraction for √2 = 1 + 1/2 + 1/2+ …

The third, fourth and eight convergent of this are exactly the approximations given above. This gives no clue to the method used in Sulva Sūtras, but the coincidence is noteworthy.

The Mānava Sulva gives the following:

40^2	+	40^2	=	56^2
4^2	+	4^2	=	$(5\text{-}2/3)^2$
36^2	+	90^2	=	97^2
5^2	+	6^2	=	$(7\text{-}5/6)^2$

The above facts make it clear that the Indians were the first to use irrational numbers. As we shall see shortly, they[269] were the first to recognize and to identify them as such. They recognized that certain numbers could not be represented as fractions no matter how many digits one used. The Greeks also used irrational numbers. If AB is a given segment, Pythagoras and others described the methods of constructing segments of length$\sqrt{2}$ AB, $\sqrt{3}$ AB,$\sqrt{5}$ AB, etc. But no rational approximations to $\sqrt{2}$, $\sqrt{3}$ etc., are found in Greek mathematics, nor are there any problems involving arithmetical operations on irrational numbers. This is easily explained, because the requisite knowledge of arithmetic was not available to the Greeks. It will also be borne in mind that according to unprejudiced estimates, the Sulva Sūtras are about two or three centuries prior to Pythagoras. We are strongly of the opinion that the Sulva Sūtras belong to the 3rd Millennium BCE.
* Source: The History of Ancient Indian Mathematics, C.N. Srinivasa Iengar

5. YĀSKA, यास्क

Yāska was a Sanskrit grammarian who preceded *Pāṇini* (fl. 4th century. BCE), assumed to have been, the first person in history to have written about etymology, and would have felt very much at home with the computational linguistics of today. The reason for developing etyma for words is mainly for mnemonic purposes. Learning the origin of a word helps us in understanding the values of a civilization. An example of the use of etymology, is the word Atithi, which means Guest in Sanskrit. Now the word Atithi is etymologically related to Tithi which means a day or a measure of time. Thus Atithi, means a Guest who can arrive at any time (but must nevertheless be welcomed) without reservation or equivocation. While not every guest in India may be welcomed in that manner, I merely highlight this as an example of how a language influences the values of the civilization.
He is the author of the Nirukta, a technical treatise on etymology, lexical category and the semantics of words. He is thought to have succeeded Śākaţāyana, an old grammarian, and expositor of the Vedas, who is mentioned in his text. The Nirukta attempts to explain how certain words get to have their meanings, especially in the context of interpreting the Vedic texts. It includes a system of rules for forming words from roots and affixes, and a glossary of irregular words, and formed the basis for later lexicons and dictionaries. It consists of three parts, namely:

Naighantuka, a collection of synonyms;
Naigama, a collection of words peculiar to the Vedas, and
Daivata, words relating to deities and sacrifices.

The Nirukta was one of the six vedāńgas or compulsory ritual subjects in syllabus of Sanskrit scholarship in ancient India.

6. ARGA (BORN 2285 BCE)

Sage Garga (born 2285 BCE), 50th in Purāṇic list of kings and sages, son of Garga, initiates method of reckoning successive centuries in relation to a Nakṣatra list he records in the *Atharva Veda* with Krittika

[269] *See Āryabhaţa in this chapter*

as the first star. Equinox occurs at Kārtika Pūrnima. A complete Nakṣatra (Constellation) list is in ubiquitous use by this date.

7. VṚDDHA GARGA



FIGURE 2 EDICTS OF ASOKADITYA IN BRAHMI

Composed the Vṛddha Gargasāṃhita. There was also a Sage Garga. One of the greatest sages of the Purāṇic times. **Garga** was the son of Riṣi Bharadvaja and Sunshield. He was better known as Garga Muni was the family priest of the family of Nanda (the foster-father of Krishna).He named Krishna as "Krishna" after receiving the name by meditation. From the Vishnu Purāṇa and other Purāṇa, one understands that although basically of Kshatriya origin, a branch of Garga's became Brāhmaṇas and migrated westwards and joined the Yavanas (not to be confused with Greeks. It is also claimed that a Vṛddha -Garga (Earlier or Older Garga) was the pioneer in astronomy.

Gargi is the celebrated female sage Vachaknavi, born in the family of Garga.

8. PĀṆINI, (पाणिनि) (2ND MILLENNIUM BCE)

Pāṇini (**पाणिनि**) was an ancient Indian grammarian c. 520–460 BCE, but estimates range from the 7th or even earlier as far back as the 17th century BCE, up to 4 centuries prior to the evolution of classical Sanskrit) who lived in Gandhara (present day Kandahar) and is most famous for his grammar of Sanskrit, particularly for his formulation of the 3,959 rules of Sanskrit morphology in the text .

Pāṇini's **grammar** of Sanskrit, which is codified in the Ashtādhyāyī, is highly systematized and technical. Inherent in its analytic approach are the concepts of the **phoneme**, the **morpheme,** and the **root**, only recognized by Western linguists some two millennia later. His rules have a reputation for perfection — that is, they are claimed to describe Sanskrit morphology fully, without any redundancy. A consequence of his grammar's focus on brevity is its highly unintuitive structure, reminiscent of contemporary "machine language" (as opposed to "human readable" programming languages). His sophisticated logical rules and technique have been widely influential in ancient and modern linguistics.

It was Pāṇini who first enunciated that grammatically, Sanskrit has eight cases for the noun (nominative, accusative, genitive, dative, ablative, instrumental, vocative, and locative – these were subsequently adopted by the European languages), three genders (masculine, feminine, and neuter), three numbers for verbs, nouns, pronouns, and adjectives (singular, dual, and plural), and three voices for the verb (active, middle, and passive). The language is very highly inflected. The ancient Indian scripts known as the Brahmi and the Kharosthi have been employed to record Sanskrit. Both Brahmi and Kharosthi are thought to be of Semitic origin. The Devanagari characters, which are descended from Brahmi, also

were, and still are, used for writing Sanskrit. The comparison of Sanskrit with the languages of Europe, especially by Sir William Jones, opened the way to the scientific study of language in Europe in the 18th cent. In fact it would not be too farfetched to say that the study of Grammar began in Europe after the discovery of Sanskrit. We take off our hats to this extraordinarily brilliant individual who achieved so much with so little nearly 4 millennia ago. There has been talk that Pāṇini, and the later Indian linguist Bhartṛhari, may have had a significant influence on many of the foundational ideas proposed by Ferdinand de Saussure, professor of Sanskrit, who is widely considered the father of modern structural linguistics.
We mention Pāṇini in this list because, without his contribution to semantics and language and possibly the elucidation of the Place Value system and the use of symbols for numbers, Algebra would not have developed in India, as it indeed did not develop elsewhere, and the resulting prowess that the Indics exhibited in Computational Astronomy might not have occurred in India.

9. LAGADHA (TERMINUS ANTE QUEM 1350 BCE)

Not surprisingly a lot more is known of the personality and interests of Lagadha, than the details of his life (birthdate, span of life, place of residence etc.). I quote from the excellent compilation of Prof. V. Kannan in the **ISERVE** publication on Ancient Indian Mathematicians[270].

"Lagadha is an author, scientist, and a poet with a wry sense of humor. He possessed a quality, which we do not value in the modern world, namely that of brevity. His facility with numbers was far ahead of Ptolemy who lived over a millennium after him. He came up with a pretty decent calendar several hundred years before Hesiod wrote his treatise on Works and days in the seventh century. Occidental historians give undue credit to the ancient Greeks for their mathematical prowess, such as for example James Evans[271] when he says "The rapid development of Greek mathematics expanded the ability of astronomy to deal with the problems of celestial motions". How he can make this statement when the Greeks were unfamiliar with algebra (and did not have the facility with Trigonometric functions) is beyond my comprehension. In fact trigonometry did not arrive in Europe till the time of Bartolomeo Pitiscus in the fifteenth century, 14 centuries after the advent of Ptolemy and 2 millennia after the Jaina mathematicians in the Indian subcontinent. So instead of throwing rocks at the Vedanga Jyotisha (VJ) as the Occidental has done, let us recognize that the VJ was a very credible effort, considering it was done 3600 years go".

10. MAHĀVĪRA (760 BCE)

(Composer of Chandraprajnāpati and Sūryaprajnāpati). See Chapter IV. Regarded as the founder of the Jaina system of beliefs, although Jainas believe that he was merely the 24th Tirthankara तीर्थंकर. Some say that the Jaina texts were written by Bhadrabāhu who is connected with the statue at Shrāvana Belgola. More work needs to be done in this area.

11. SPHUJIDVAJA (YAVANESWARA) 269 BCE

270 "Ancient Indian Mathematicians", ISERVE Publication, released on the occasion of the International Congress of Mathematicians", Hyderabad, 19th to 27th August, 2010
271 History and practice of astronomy, p.10

Bhatotpala (Bhatta Utpala), in his commentary on Brihat Jātakam 7/9 says, "Yavaneswara Sphujidwaja composed another work on astrology immediately after the start of Ṡaka Era i.e. 78 AD. VarāhaMihīra has also written the opinions of the predecessors of Yavaneswara. I have not seen the astrological works of earlier Yavanāchāryas but I have seen the work of Sphujidwaja". It means that the Yavanajātaka of Sphujidwaja was available at the time VarāhaMihīra (fifth century CE and also Bhatotpala (eighth century CE). Similarly, Alberuni says on page 158 of his Al Biruni's India Vol. I, "There is another book larger than this (i.e. Kalyan Verma's Saravali) which contains the whole of astrological sciences of Yavana, i.e. belonging to the Greeks".
Pt. S. B. Dikshit has said on page 637 (Hindi translation) of Bharatiya Jyotish, "Bhatotpala has called Sphujidwaja as Yavaneswara and the ṣlokas he has quoted as from Yavanas are from that very book. This work is in Sanskrit. There is also available a work by Minaraja. It is also known as Vridha Yavana Jātakam. It has been said in that book (i.e. Vridha Yavana Jātakam) that the work of astrology of one hundred thousand verses that had been revealed to Maya by earlier jyotish have been compressed into 8000 by Minaraja.

FIGURE 3 CONCEPTS IN UMASWATI'S TATTVĀRTHĀDHIGAMA-SŪTRA BHĀŚYA (TERMINUS ANTE QUEM 150 BCE)

The Versine or Sara (Utkramjya) Sara $\theta = s/r$

The Sara (Utkramjya) Function or the Versine appears in Jaina literature prior to the Sūrya Siddhānta, before Hipparchus,

d= diameter of circle= AE = 2 OB = 2r, c = BC = Jya θ

ch = chord subtended by angle 2θ = BD = 2c

CO = Kojya or Kotijya θ = □ $(r^2 - c^2)$

Bhatotpala has quoted (chapter 1/5) the forms of Raṣis etc. and they have been taken from Minaraja's book but there are several other verses that are not available in Vridha Yavana Jātaka. It means the work of Sphujidwaja is different from that of Minaraja and the other Yavanāchāryas of ages prior to Varāha Mihīra as also other Yavanas besides the two i.e. Sphujidwaja and Minaraja".

12. UMĀSVĀTI (UMĀSVĀMI)

It is certain that he lived in the city of Kusumapura, which later became to be called Pataliputra (near Patna). The existence of a school of mathematics at Kusumapura or Pataliputra from about the first century BC seems to be fairly certain, and the school continued there for several centuries, for Āryabhaţa (born 476 CE) also belongs to the Kusumapura School. Umāsvāti's name has come down to us as a great writer on Jaina metaphysics, but his credentials as a mathematician are unclear. It is to be concluded that the mathematical formula and results quoted in his work were taken from some treatise on mathematics extant in his time. For now Umāsvāti well have to serve as a proxy for this unknown mathematician. If he

wrote the Bhāṣya, the Sūtra must predate him. Amongst the mathematical results contained in the Tattvārthādhigama Sūtra Bhāṣya are a number of mensuration formulae.

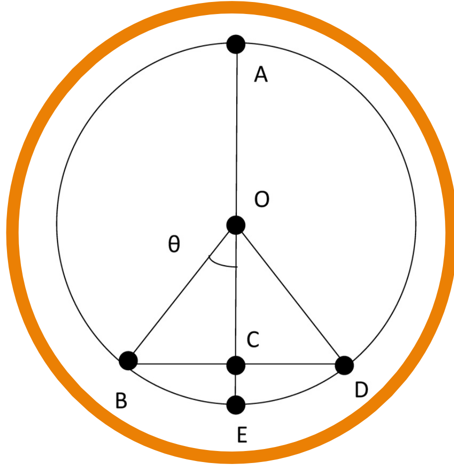


FIGURE 4 EXPLANATORY GEOMETRY FOR JAINA TEXT

(1)Circumference of a circle = √10 x diameter(2) area of a circle= 1/4 X circumference X diameter (3) chord = √(4 sara (diameter— sara) (4) sara = |1/2 X [diameter — √(diameter^2 — chord^2)]

(5) arc of segment (less than a semicircle) = √(6 X sara^2 + chord^2)

(6) diameter = [sara^2+ (1/4 X chord^2)]/ sara, (means the height or the arrow of the segment).

13. BAKṢĀLĪ MANUSCRIPT

In May 1881 CE, a farmer in the North West Frontier Province at Bakṣāli near Mardan (in what is now Pakistan) while doing some routine excavations on his land, found a mathematical work written on birch-bark.

Bakṣāli is 4 miles north of Shāhbāzgarhi. The farmer reported that he found the manuscript while digging in a ruined stone enclosure. According to the finders statement the greater part of the manuscript was destroyed while extricating it from the place where it lay between stones in a ruined stone enclosure on one of the mounds. These mounds lie on the west side of Mardan and obviously represent the former remains of a village. All that remained were about 50 pages with writing easily legible as one of the Prākrit languages called Goth. The manuscript was later edited and printed by G.R. Kaye, who was especially noted for his mendacity towards anything that reflects well on the Indian. He promptly classified it as being a document of the 12th century CE. Datta believes that the manuscript has a terminus ante quem of 3rd or 4th Century and could have been a commentary on a much older document.

FIGURE 5 GEOGRAPHICAL LOCATION OF BAKṢĀLĪ



Gurjar[272] discusses the date of the manuscript in detail, and concludes it can be dated no more accurately than 'between 2nd century BC and 2nd century AD'. He offers compelling evidence by way of detailed analysis of the contents of the manuscript (originally carried out by R. Herne). His evidence includes the language in which it was written ('died out' around 300 AD), discussion of currency found in several problems, and the absence of techniques known to have been developed by the 5th century. Further support of these dates is provided by several occurrences of terminology found only in the manuscript,

[272] *L V Gurjar, Ancient Indian Mathematics, and the Veda (Poona, 1947).*

(which form the basis of a paper by M. Channabasappa). However, earlier scholars have tended to date it around 400 CE (Hoernle, Datta/Singh, Bag, and Gupta). Hayashi had suggested a possible seventh century date, while in an early colonial estimate; G.R. Kaye had assessed it to be as late as 12th century CE. Such late dates are quite unlikely because the language used was already dying by the 4th century CE; also the work does not mention integer equations and other topics which were of widespread interest after Āryabhaṭa (5th c. CE). Today, Kaye's assessment is widely discredited as being heavily corrupted by bias and prejudice.
The reason why the date of the manuscript is important, is that if the work indeed dates from the 3d century or earlier, it would corroborate what was already widely suspected that the use of Zero and the concept of the mathematical zero was known several centuries earlier than the work of Brahmagupta in the 7th century who codified the rules associated with the use of Zero.
The manuscript gives the sum of a finite number of fractions by reducing them to a common denominator; gives the sum of n consecutive terms of an arithmetic or geometric progression and another interesting piece of mathematics in the manuscript concerns calculating square roots which is equivalent to the determination of approximate values of quadratic surds. This formula is usually attributed to Heron of Alexandria[273] in the 2nd century CE and is originally attributed to the Babylonians in the form of a series approximation.

The following formula is used:

$\sqrt{A} = \sqrt{(a^2 + r)} = a + r/2a - (r/2a)^2 / (2(a + r/2a))$
This is stated in the manuscript as follows:-
In the case of a non-square number, subtract the nearest square number, divide the remainder by twice this nearest square; half the square of this is divided by the sum of the approximate root and the fraction. This is subtracted and will give the corrected root.
Taking $A = 41$, then $a = 6$, $r = 5$ and we obtain 6.403138528 as the approximation to $\sqrt{41} = 6.403124237$. Hence we see that the Bakṣāli formula gives the result correct to four decimal places.
The Bakṣāli manuscript also uses the formula to compute $\sqrt{105}$ giving 10.24695122 as the approximation to $\sqrt{105} = 10.24695077$. This time the Bakṣāli formula gives the result correct to five decimal places.
The following examples also occur in the Bakṣāli manuscript where the author applies the formula to obtain approximate square roots:
$\sqrt{487}$
Bakṣāli formula gives 22.068076490965.
The correct answer is 22.068076490713.
Here 9 decimal places are correct
$\sqrt{889}$
Bakṣāli formula gives 29.816105242176.
The correct answer is 29.8161030317511.
Here 5 decimal places are correct.
[Note. If we took $889 = 30^2 - 11$ instead of $29^2 + 48$ we would get
Bakṣāli formula gives 29.816103037078
Correct answer is 29.8161030317511
Here 8 decimal places are correct
$\sqrt{339009}$
Bakṣāli formula gives 582.2447938796899.

273 *Heron of Alexandria*

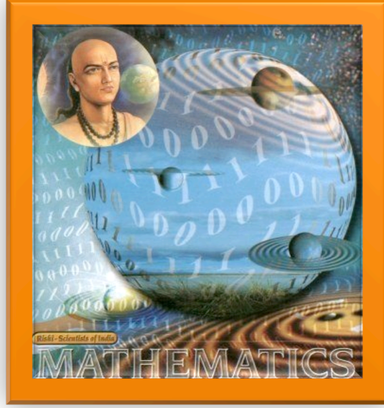
The correct answer is 582.2447938796876.
Here 11 decimal places are correct

It is interesting to note that Channabasappa derives from the Bakṣāli square root formula an iterative scheme for approximating square roots. He finds in that it is 38% faster than Newton's method in giving √41 to ten places of decimals. The other interesting aspect of the Bakṣāli manuscript was the fact that it uses the formula for square roots to estimate the error for any given number of terms in the series as indicated in the excerpt from Srinivasa Iengar's book earlier in this chapter in the section on the Sulva Sūtra and the calculation of surds.

14. ĀRYABHAȚA

In 499 CE, in Kusumapura, capital of the Magadha Empire in classical India, a young mathematician named Āryabhaţa published an astronomical treatise written in 118 Sanskrit verses. A student of the Vedic mathematics tradition that had slowly emerged in India between 4000 BCE and 900 BCE, Āryabhaţa, only 23, intended merely to give a summary of Vedic mathematics up to his time. But his slender volume, the Āryabhaţīya, was to become one of the most brilliant achievements in the history of mathematics, with far-ranging implications in the East and West. It is now recognized that Āryabhaţa's work was seminal for the guture development of astronomy.

FIGURE 6 ĀRYABHAȚA



Āryabhaţa correctly determined the axial rotation of the earth. He inferred that planetary orbits were elliptical, and provided a valid explanation of solar and lunar eclipses. His theory of the relativity of motion predated Einstein's by 1400 years. And his studies in algebra and trigonometry, which laid the foundations for calculus, influenced European mathematicians 1,000 years later, when his texts were translated into European languages from 8th century Arabic translations of the Sanskrit originals.

"Āryabhaţa is the first famous mathematician and astronomer of Ancient India". Full fifteen centuries have passed in 1976 since the birth of Āryabhaţa this outstanding Indian mathematician and by acclamation the Astronomer Laureate of Ancient India.

ĀRYABHAȚA'S DATE OF BIRTH

Our knowledge of the scholar's life is very scarce. We do not know who his parents were, or his teachers, or even the exact time of his death. *Āryabhaţa* was just 23 years old when in 499 CE he completed the famous Āryabhaţīya**,** the only work of his to be preserved till our time. *In this book Āryabhaţa provides his birth data. In the 10th stanza, he says that when 60 x 60 = 3600 years elapsed in this Kali Yuga, he was 23 years old.* Writes Āryabhaţa: "*When sixty times sixty years and three quarter **Yuga** (of the current **Yuga**) had elapsed, twenty-three years had then passed since my birth".* There are several problems with the verse that states that he was 23 years old when 60 * 60 years had elapsed

after the start of the Kaliyuga[274]. Bhāskara I refers to Āryabhaţa as having lived a very long time ago. He uses the phrase काले महति[275], and certainly 130 years does not on first blush appear to qualify as a काले महति. In the same ṣloka he asserts that Āryabhaţa's fame has crossed the bounds of Oceans. It does not seem likely that his fame would have spread so fast (130 years).

The alternate version of the stanza of the ṣloka starts with
षष्ट्यब्दानां षड्भिर्यदा व्यतीतास्त्र यश्च युगपादाः ।

"Shastiabdānām Shadbhiryada vyātītāstra yascha yuga pādāha."
"Shastiabdānām Shadbhi" means 60 x 6 = 360.
While printing the manuscript, the word "Shadbhi" was altered to "Shasti", which implies 60 x 60 = 3600 years after Kali Era. As a result of this intentional arbitrary change, Āryabhaţa's birth time was fixed as 476 CE. Since in every genuine manuscript, we find the word "Shadbhi" and not the altered "Shasti", it is clear that Āryabhaţa was 23 years old in 360 Kali Era or 2742 BCE. This implies that *Āryabhaţa* was born in 337 Kali Era or 2765 BCE. And therefore could not have lived around 500 CE, as manufactured by the Indologists to fit their invented framework. We do not believe either of these dates can withstand scrutiny and the proper dating of *Āryabhaţa* is yet to be carried out in a satisfactory manner that will withstand a hermeneutic study of his writings.
The implications are profound, if indeed this is the case. The zero is by then in widespread use and if he uses Classical Sanskrit then he antedates *Pāṇini* . Here is another version of the verse which makes a big difference

षष्ट्यब्दानां षष्टिर्यदा व्यतीतास्त्र यश्च युगपादाः ।

त्रयधिका विंशतिरब्दास्तदेह मम जन्मनो अतीतः।। 10

Ṣaṣtyabdhānām ṣaṣtiryadha vyātītāstra yascha Yuga pādāha|
Trayadhika vimsatirabdhāstadheha mama janmano atīta||

"*When sixty times sixty years and three quarter yugas (of the current yuga) had elapsed, twenty three years had then passed since my birth*" (K. S. Śukla).
"*Now when sixty times sixty years and three quarter Yugas also have passed, twenty increased by three years have elapsed since my birth*" (P. C. Sengupta).
"*I was born at the end of Kali 3600; I write this work when I am 23 years old i.e., at the end of Kali 3623" "(T. S. Kupanna Sastry[11]).*

How is the chronology linked with the dates of Indian astronomers? The ancient Indian astronomers perhaps purposely linked the determination of their dates of birth, composition of their works, calculation of number of years elapsed, etc., based on two eras Kali and Śaka. Therefore, without the significance of these two eras, the dates cannot be determined specifically. There is more than one aspect of this sloka that is troubling, but we will allude to his use of the words 'three quarters of a yuga'. Most have interpreted it to mean that 3 of the 4 yugas have already elapsed, namely the Kṛta Yuga, Treta Yuga, the Dwapara Yuga and that we are in the midst of the Kaliyuga. But Āryabhaţa had proposed a much simpler Yuga system where all the constituent Yugas are equal length. . The question then

[274] This sloka was reconstructed by Bhao Daji in the mid 19th century. But there is need for verification that it is indeed an authentic reconstruction and that the original sloka was not tampered or altered
[275] In the 2nd sloka of Laghu Bhāskariyam

becomes, whether he meant this new Yuga system or the traditional one.

Here, though, only Yuga is mentioned, Kaliyuga is implied and its starting of 3101 BCE is taken for reckoning purpose. Thus, the date of Āryabhaţa is determined as follows:
The year of birth = 3600 – 3101 = 499 / 499 – 23 = 476 CE. This date is generally considered as the accepted date by most of the scholars even though we feel that there are serious problems with this date. Had the commencement year 3101 BCE been a myth or not an astronomical one, the year of Āryabhaţa could not be determined like this using 3101 BCE.

According to the Indian tradition, there are four epochs, or **Yuga** — the Golden Age, the Silver age, the Bronze Age, and the Iron Age — and the last of these, the **Kaliyuga**, began in 3101 BCE. It is from its beginning that sixty times sixty years had elapsed, i.e. Āryabhaţīya was written in 499 CE by the twenty-three-years-old author, which permits fixing 476 CE as the year in which he was born. According to another version, this ṣloka was not to be found in the extant texts it was inserted in the Nineteenth century by Bhau Daji as the most logical reconstruction of the verse. We need to find a vulgate text in order to confirm this date or the alternate date of 2765 BCE and we feel that Bhao Daji's reconstruction of the verse is suspect, if indeed it is verified that he reconstructed that verse.

To summarize the reasons why we are uncomfortable with the 476 CE date;

1. The use of the words काले महति by Bhaskara I indicates a very long period of time, and I would wager that the use of these words belies the 100 years that separate the two.
2. Kusumapura is a very ancient name. The city where the Magadha Empire flourished was known as Rajgriha, Girivraja, or Pataliputra during various eras. It is not clear under whose reign the capital of Magadha was known as Kusumapura. More work needs to be done to establish the identity of Kusumapura, as well as the birthplace of Āryabhaţa, namely the Asmaka country.
3. When one examines the first part of the sloka, it is not clear what he means when he says '3/4 of a Yuga has already elapsed'. What is the definition of Yuga that he uses;
षष्ट्यब्दानां षष्टिर्यदा व्यातीतास्त्र यश्च युगपादाः *Ṣaṣtyabdhānām ṣaṣtiryadha vyātītāstra yascha yuga pādāha*
   a. does he mean 3 of the 4 yugas in a Mahāyuga
   b. does he mean ¾ of kaliyuga, and if so what is the length of the kaliyuga that he uses ?
   c. AB has been known to propose a rationalization of the Chaturyuga system, where each Yuga is of the same duration as any other. If so what is the start date of the current kaliyuga?
   d. if he is using the ascending- descending version of the yuga system as expounded by swami Sri Yukteṣwar (see, chapter III page 163), then we have to make an assumption whether we are in the ascending or descending phase of the kaliyuga and whether he is referring to the part of a yuga when he says ¾ of a yuga.
4. The values of the astronomical constants, such as the length of the sidereal year and the sidereal month are changing with time. If we accept that premise, and that AB was very accurate *Āryabhaţa*'s values indicate a much higher antiquity than 476 CE.

While the 2765 BCE date seems to be of rather a high antiquity the 476 date is not very satisfactory for the reasons mentioned above. We feel that an appropriate date for the terminus ante quem date of Āryabhaţa is around 500 BCE after the Jaina contributions and after the date of the Sūrya

Siddhānta which is also the most likely date mentioned by Colebrooke. The upshot of this brief foray into the chronology of Āryabhaţa is that the chronology of the main events in Āryabhaţa's life cannot be designated as a settled issue. We are tending towards the explanation that there were 2 Āryabhaţa's (in addition to the 3rd Āryabhaţa in 950 CE)

The exact place of *Āryabhaţa*'s birth is unknown. The treatise only mentions a major Indian scientific centre — Kusumapura (Pātaliputra, modern Patna in Bihar), where the scholar may have worked: "Having bowed with reverence to Brahma, Earth, Moon , Mercury, Venus, Sun, Mars, Jupiter, Saturn and the asterisms, Āryabhaţa sets forth here the knowledge honored at Kusumapura" (see ref, 1, part II, rule 1). Some authors believe him to be a native of Asmāka, a province in Southern India (p. 93), but that view is not shared by everybody. We are inclined to believe that the story about his being from Asmāka country is true and that the Asmāka country is the Godavari River valley, on the upper reaches of the Godavari river, where his forbears immigrated from the Sarasvati River valley, which would explain why some of his biographers feel that he hails from the Northwest of the Indian peninsula.

Of his personal biography we know nothing more, but we have got something far more precious — the work which was indeed a turning point in the history of exact science in India. In a way, Āryabhaţīya was an interface work which took of previous development and as far as was possible had imbibed the best achievements of preceding epochs. But on the other hand, it marked the start of a new scientific tradition in India and was studied and analyzed over the centuries. Twelve commentaries to the work are on record, the earliest dating back to the first quarter of the 6th century and the latest to the mid-19th century. The commentators include famous Indian mathematicians and astronomers, notably Bhāskara I (7th century), Parameşvara (15th century), and Nīlakaņţa (15th - 16th century). Quite a few manuscripts of some of the commentaries have been preserved which is an indication that Āryabhaţīya was studied rather extensively. This is also indicated by commentaries in vernacular languages. The original Sanskrit treatise had been translated into vernacular Hindi, Telugu, and Malayalam and was studied thoroughly.

Apart from his main work, Āryabhaţa had written a work on astronomy, which was known as ***Āryabhaţa-Siddhānta***, but it has not been preserved. Āryabhaţīya is a relatively small work written in traditional Indian form of distinctly metrical verses made up into the four parts of the treatise: ***Dasagitika*** or the Ten ***Giti*** Stanzas; ***Gaņitapada*** or Mathematics; ***Kalakriya*** or the Reckoning of Time; and ***Gola*** or the Sphere. It is in Āryabhaţa's exposition that a number of mathematical rules have come down to us. Mathematical matter is enunciated, not just in the special second part, but throughout all other chapters.

The treatise does not elaborate on the ways by which rules were obtained and one has to study the Bhāşya Commentaries for elaboration of derivations of proofs or conclusions. The presentation is as succinct as could be, with all rules stated in the form of advice or prescription. Āryabhaţīya treats of diverse problems of arithmetic, algebra, geometry, theory of numbers, trigonometry and astronomy'.

One of the most significant contributions to world science which was made by Indian mathematicians is the establishment of decimal place-value system. The earliest arithmetic rules known to us in this system were described by Āryabhaţa in Āryabhaţīya***,*** namely the square-root and cube-root evaluation.

Closely related to the decimal place-value system was the alphabetic numeration also given by Āryabhaţa? Such numerations were aimed at reducing the long strings of words arising when numbers are written in a verbal form.
A central part in the arithmetic part of all Indian works was held by the Rule of Three or Rule of Ratio and Proportion, teaching us how to find a number ***x*** , when it stands in relation to another number ***C***, in the same ratio as **2** other numbers (***a,b***).

$$\frac{c}{x} = \frac{a}{b}$$

Many problems were reduced to an application of this rule. Indian scholars had coined a name for each term of the proportion and, in fact, gave its name to the rule itself. From the Indian the Rule of Three passed over into Arabic and thence into West European mathematical writings.

The types of problem subject to the Rule of Three had been certainly known elsewhere — in China, Greece, and Egypt, but it was only in India that the rule was singled out, translated into problem solving methods, and extended to the case of five, seven, etc. quantities. These extensions seem to have been familiar to Āryabhaţa, even though he cites only the Rule of Three. In his commentary, Bhāskara I writes: "Here Acharya *Āryabhaţa* has described the rule of three only. How the well known rules of five, etc. are to be obtained? I say thus: The Acharya has described only the fundamental relation of ***anupata*** (proportion). All others such as the rule of five, etc. follow from the fundamental rule of proportion. How? The rule of five, etc. consists of combinations of the rule of three. In the rule of five there are two rules of three, in the rule of seven, three rules of three, and so on".
The treatise considers several problems which reduce to solving a linear equation in one unknown. One problem, set forth in part II, rule 30, is to calculate the value of an object if it is known that two men having equal wealth possess a different number of objects, a_1 a_2 and different pieces of money remaining after the purchase, b_1, b_2. The problem reduces itself to solving the equation $a_1x + b_1 = a_2x + b_2$. Āryabhaţa formulates the rule of solving the linear equation in this manner: "Divide the difference between the ***rupakas*** with two persons by the difference between their ***gulikas***. The quotient is the value of one ***gulika***, if the possessions of the two persons are of equal value" (See ref. 1, part II, and rule 30). That is to say, $X = \frac{b_2 - b_1}{a_1 - a_2}$
Another problem is the famous Problem of Messengers, which later peregrinated all over the world in algebraic literature. It is to calculate the time of meeting of two planets moving in opposite directions, or in the same direction. Āryabhaţa formulates this rule: "Divide the distance between the two bodies moving in the opposite directions by the sum of their speeds, and the distance between the two bodies moving in the same direction by the difference of their speeds; the two quotients will give the time elapsed since the two bodies met or to elapse before they will meet" (Gaṇitapada, rule 31).
Thus, if the distance S between the two bodies and their velocities V_1 and V_2 are known, the time of meeting is found as $\mathbf{t} = \frac{S}{V_1 \pm V_2}$ with a plus sign.
When they are moving in opposite directions or as when they are moving in the same directions, use the minus sign. Noteworthy, is the fact that Āryabhaţa formulates the solution in such a way as to avoid introducing negative numbers, which Indian scholars, beginning with Brahmagupta (7th century) later adopted and used quite regularly. Several problems in Āryabhaţīya lead to quadratic equations, in particular, the finding of the number of terms in an arithmetical progression and the calculation of interest. In the latter case, the following problem is solved, which is quoted by one of *Āryabhaţa*'s commentators: capital A yields an unknown monthly profit x, which is then itself lent for interest for T

months. The initial profit added together with the new interest is equal to B. Find the initial interest rate.

Āryabhaţa gives the solution of the quadratic equation **$Tx^2 + Ax = AB$** in verbal form corresponding to this expression:

$A_1 = A/2$

$A_2 = (BAT + A_1^2)$ ½

$x = (A_2 - A_1)/T$

Similar problems of compound interest are posed by many Indian authors. They also occur in European manuals belonging to modern history. For example, the first problem of quadratic equations in ***Elements d'algèbre*** by A. Clairaut (1746) is for compound interest.

Beginning with *Āryabhaţa*, most Indian mathematical texts give rules and examples of arithmetical progression. Āryabhaţa knew the rules for the general term, sum, and the number of terms of an arithmetic progression. The rules for the summation of an arithmetical progression are set forth by *Āryabhaţa* in the part II, rule 19: "Diminish the given number of terms (n) by one, then divide by two (we call this n_1), then increase by the number of the proceeding terms (if any), then multiply by common difference (d), and then increase by the first term of the (whole) series (p) : the result is the arithmetic mean (of the given number of terms). This multiplied by the given number of terms is the sum of the given terms. Alternatively, multiply the sum of the first and last terms (of the series or partial series which is to be summed up) by half the number of terms" The first part of the rule finds the sum S of the terms of an arithmetical progression from the term p+1 to the term ***p+n:***

$n_1 = (n-1)/2$

$S = n[a + (n_1 + p)d]$

The second part of the rule gives the formula $S = (a_1 + a_2)n/2$ in the more familiar form. Āryabhaţa also formulates the rules for finding the number of terms of an arithmetical progression for a given sum S.

$d_1 = \{8 d S + (d - 2a)^2\}^{1/2}$

$n =$ ½ $[(d_1 - 2a)/d + 1]$

Āryabhaţīya states the rules for the summation of natural squares and cubes, as well as some other series, which, however, had been previously known to Babylonians and Greeks. Āryabhaţa contributed enormously to the theory of numbers and its important topic — the indeterminate equations. The problem first arose in India from calendrical calculations while satisfying astronomical needs for determining the periods of repetition of certain relative positions of celestial bodies (the Sun, the Moon, and the planets) which had different revolution periods and from other related issues. The problem reduces itself to finding integer numbers which divide by given remainder, i.e. satisfying indeterminate linear equations and equation systems.

In the third century CE, the Greek mathematician Diophantus was concerned with indeterminate equations, but he only was seeking for rational solutions. Beginning with Āryabhaţa, the Indians tried to solve these equations in positive integers, which was a far stronger proposition. Any direct Greek influence on the Indian scholars is unlikely here, for each school had arrived at problems of the theory of numbers proceeding from different needs and using different methods. One may rather suppose some contacts of Indians linking them to ancient Chinese mathematicians, who had likewise arrived at indeterminate equations proceeding from the needs of astronomy and the problems of remainder and, moreover, also were only seeking after integer solutions (See ref. 8 pp. 143-144). Āryabhaţa's contribution to the theory of numbers was very valuable indeed; he was the first in the world literature to formulate very elegant methods of integer solution of indeterminate equation of the first degree.

Āryabhaţa gives the pertinent rule in part II of, rule 32-33 for the Solution of this problem: find a number N, which, when divided by given numbers a, c yields two known remainders p, q. The problem leads to these indeterminate equations of the first degree:

ax + b = cy, if p > q (b = p - q)
ax - b = cy, if p < q

Incidentally, the latter equation can be reduced to the former by substitution of the unknown.
Āryabhaţa 's rule is stated in an extremely succinct formulation, which had given rise to a great deal of comment and debate.
Āryabhaţa's geometrical rules include several verbal formulas. For example, he defines the area of a triangle as the product of the height multiplied by a half of the base (See ref. 1, part II, rule 7) as a half of the circle's length multiplied by a half of the diameter.
The area of any plane figure, writes Āryabhaţa in part II, rule 9, can be found if we single out two sides and then multiply one by the other. The commentator Parameșvara explains that what is meant here is the mean length and width.
Āryabhaţa determines the volume of a pyramid as base area multiplied by half the height. This, rather rough approximation is refined by other mathematicians, and in particular by Sridhara, who finds the volume as the base area multiplied by a third of the height. Āryabhaţa calculates the volume of a sphere by the formula $\pi r^2\sqrt{\pi r^2}$, which is equal to $1{\bullet}47\pi r^3$. This is rather approximate as compared with the exact formula for the volume of the sphere, given by Bhāskara II $\frac{4}{3}\pi r^3$.

Add four to one hundred, multiply by eight, and then add sixty-two thousand. The result is approximately the circumference of a circle of diameter twenty thousand. By this rule the relation of the circumference to diameter is given (= 62832/2000).

In part II, rule 14, Āryabhaţa gives the Pythagorean Theorem: "Add the square of the height of the

THE FIRST ACCURATE VAUE OF π TO 5 SIGNIFICANT PLACES

An essential mathematical constant, which also had a great practical value, was π the number estimating the ratio of the length of a circle of its diameter **π**. For his time, *Āryabhaţa* 's estimation was rather accurate (ref. 1, part II, rule 10). The value which was given by Āryabhaţa is correct to four decimal places: **π ≈ 3.1416.** See Appendix O, where the value of PI is tracked through the centuries.

चतुराधिकं शतमष्टगुणं द्वाषष्टिस्ता सहस्राणाम् ।

अयुतद्वयविष्कम्भस्यासन्नो वृत्तपरिणाहः ॥ 10

Chaturādhikam śatamaśţaguṇam dvāșașţistathā sahasrāṇām
Ayutadvayaviśkambhasyāsanno vrîttaparināhah**.**

gnomon to the square of its shadow. The square root of that sum is the semi-diameter of the circle of

shadow".

In part II, rule 13, the scholar gives several geometrical definitions which are rather rare in Indian mathematical literature: "A circle should be constructed by means of a pair of compasses; a triangle and quadrilateral by means of the two hypotenuses. The level of ground should be tested by means of water; and verticality by means of plumb". A look at some of the geometrical problems considered by Āryabhaţa shows that he knew the basic properties of similar triangles and proportions, had an idea about derived proportions, relations of the segments of two intersecting chords, and the properties of the diameter perpendicular to a chord.
The trigonometric problems expounded in Āryabhaţīya are outstanding. The Occidentalist viewpoint is a highly jaundiced one that Āryabhaţa plagiarized from XYZ. You can name your country, as long as it is not India. It does not really matter to the Occidentals where he plagiarized it from; their sole intent is to show that the Sine tables that he derived are originated anywhere but from India. But the Indians replaced chords with sines, which enabled them to introduce various functions related with the sides and angles of the right-angled triangle. They considered the Sine function, the Cosine function, and the function which was later in Europe named the sinus-versus, or versed sinus. The earliest sine table is found in ***Sūrya-Siddhānta*** and in the Āryabhaţīya. The table is compiled with a step of 3°45' = 225', i.e. 1/24 of the quadrant arc.
Āryabhaţa, as well as other Indian mathematicians made a wide use of the shadow cast by a vertical pole, the gnomon (Shanku–yantra), to determine heights and distances. A number of relevant rules and problems are given in the geometrical chapter. This anticipated the introduction of tangent and cotangent, which were introduced in the 9th century by mathematicians in Islamic countries; incidentally, these functions were described by the name of "shadows".

CONTRIBUTIONS OF ĀRYABHAŢA IN MATHEMATICS AND ASTRONOMY

How far-reaching was the true mathematical contribution of Āryabhaţīya***?*** It encompasses:

- The first description of the rules in the decimal place-value system;
- The first description of the alphabetic numeration which had played a great role in the development of mathematics;
- One of the founders of Algebra, although named after Al Khwarismi, which is a Eurocentric view, that nothing worthwhile originated in India.
- He was the first to enunciate the notion that an infinite series can approach a quantity, but will always remain an approximation. The notions of Asanna and Aviṡiṣṭa were first introduced by him.
- The first Indian description of the evolution of the square root and the cube root;
- The treatise considers several very interesting problems, which had played a great role in the development of mathematics;
- Āryabhaţa was also the first to formulate the rule of integer solution of indeterminate equation of the first degree in two unknowns;

$$\boldsymbol{N = ax + b = cy + d = ez + f = \cdots}$$
$$\boldsymbol{N = \frac{ax \pm b}{c}}$$

- He set forth the methods of finding the general term, the sum, and the number of terms of an arithmetical progression in this endeavor he was far in advance of anything the rest of the world had to offer.

For his time *Āryabhaţa*'s estimation of π was very accurate; 3.1416. He gave the value of PI correct to four decimal places, but more importantly, mentioned that this value could only be *'asanna'*, or approximate! It was only a 1000 plus years after Āryabhaţa that the western world came to recognize this feature of PI.

- In just one stanza (the first line of which we would have read in the previous paragraph), he gives the rule for drawing up the sine table for values of angles from 0 degrees to 90 degrees, at intervals of 3º45'. His methods of computing the sinus-table in trigonometry was a brilliant contribution to computational science and anticipated the use of Recursion in Algorithms, which are very common in computerized subroutines. He should rightfully be regarded as the founder of trigonometry
- He had a very mature view of mathematical models. He observes that just as we use analogies to visualize true events, the astronomers employ notions such as madhyama, mandocca, sighrocca, sighra paridi, jya, kastha, koti etc in order to derive the observed motions of planets. Hence, there is indeed nothing unusual that fictitious means are employed to arrive at the true result. In other words he did not deify the model as an ontological principle ordained by a higher power (as Greeks and their successors, the church did repeatedly) in the Occident.

Those are just the principal mathematical innovations appearing in Āryabhaţa's treatise. But this rundown by no means fathoms the deep and important role that ***Āryabhaţīya*** played in the development of Indian and world science.

His achievements in the field of Astronomy are equally extraordinary

- Disagreeing with the majority of his time, he stated that the earth is spherical or circular in all directions "Bugolah sarvato vruttah", he said.
- He was the first Indian astronomer to recognise that the earth and other planets are not self-luminous: "Halves of the globes of the earth and the planets are dark due to their own shadows; the other halves facing the sun are bright," he said.
- He explicitly mentions that the luminous heavenly bodies, despite being stationary appear to move from east to west - "*Acalāni bhani samapashchimagani",* he said.
- He gave a remarkably accurate measure of the period of one rotation of the earth with reference to the fixed stars in the sky, as **$23^h\ 56^m\ 4.1^s$**. The corresponding modern value is $23^h\ 56^m\ 4.091^s$! He has computed the number of revolutions likely to be made by the planets in one *mahāyuga*, the traditional duration of which time period is considered as being 4,320,000 years.
- Towards the end of the eighth century, the treatise was translated into Arabic under the title of ***Zij al-Arjabhar***. About the same time, two works by Brahmagupta were also translated which carried some of Āryabhaţa's mathematical and astronomical innovations. Later, when Arabic scholarly tests were translated into Latin, some of Āryabhaţa's ideas were inherited by West European scientists.

India paid Āryabhaţa the signal honor of naming its first space satellite after him on April 19, 1975. It was a fitting tribute to a man whose mind was not shackled by appearances. He was truly a Riṣi, a Seer of the highest caliber a Mahārishi, who was able to see that which is not visible to others.

15. VARARUCHI (ONE OF THE NAVARATNAS OF VIKRAMĀDITYA) FL CA 57 BCE

Vararuchi's **वररुचि** name appears in a Sanskrit verse specifying the names of the 'nine gems' (navaratnas) in the court of the legendary King Vikramāditya. The Vikrama era starting in 57 BCE, was named after this legendary king. This verse appears in *Jyotirvidabharana*, which is supposed to be a work of the great Kālidāsa but is in fact a late forgery. This verse appears in the last chapter (Ṣloka 20: Chapter XXII) of *Jyotirvidabharana*. That the great Kālidāsa is the author of Jyotirvidabharana is difficult to believe because Varāhamihīra, one of the nine gems listed in the verse, in his Panchsiddhāntika refers to Āryabhaṭa, who was born in 476 CE and wrote his Āryabhaţīya in 499 CE or a little later. *Jyotirvidabharana* is a later work of about twelfth century CE.

There might have been a much respected Vararuchi in the court of King Vikramāditya, but the Occidental Indologists have hopelessly obfuscated the identity of King Vikramāditya, and finally when they could not resolve the contradictions in their chronology, they declared him a persona non grata, existing only in the virtual world of the Hindu nationalist.

16. VARĀHAMIHĪRA (CONVENTIONAL 499-587 CE, PROPOSED FL. 123 BCE) EMINENT ASTRONOMER, SON OF ĀDITYADĀSA

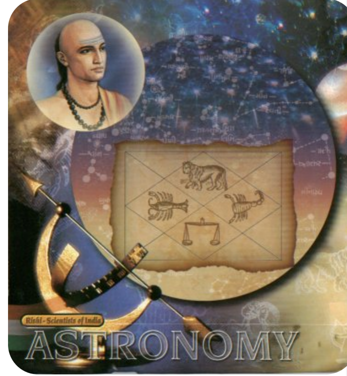
Varāhamihīra was a renowned astrologer and astronomer honored with a special status as one of the nine gems in the court of King Vikramāditya in Avanti (Ujjain). *Varāhamihīra*'s book "Panchsiddhānta" holds a prominent place in the realm of astronomy. He notes that the moon and planets are lustrous not because of their own light but due to sunlight. In the "Brihat Saṃhitā" and "Brihat Jātaka," he has revealed his discoveries in the domains of geography, constellation, science, botany, and animal science. In his treatise on botanical science, Varāhamihīra presents cures for various diseases afflicting plants and trees. The Riṣi-scientist survives through his unique contributions to the science of astrology and astronomy. Please note that there is a contradiction in the chronology, if we accept that he was one of the 9 Navaratnas of Vikramāditya's court .then his dating would be contemporaneous with the Reign of Vikramāditya and the Vikrama Era (55 BCE).

In the Panchasiddhantika[27] there occurs the following sloka[28]

सप्ताश्वि वेद संख्यं शाककालमपास्य ट चैत्र शुक्लादौ ।

अर्द्धास्तमिते भानौ यवनपुरे सौम्या दिवसाद्ये

saptāśvi vēda saṁkhyaṁ śākakālamapāsya ṭa caitra śuklādau |
arddhāstamitē bhānau yavanapurē saumyā divasādyē



The names of the 9 Navaratnas were:

Dhanvantari
Kshapanak
Amarasimha
Shanku
Vetal Bhatt
Ghat karpar
Varāhamihīra
Vararuchi

Kālidāsa was the most notable among all of them.

DAIVAJNA VARĀHAMIHĪRA वराहमिहीर**;** also called Varāha, or Mihīra was an Indian astronomer,

mathematician, and astrologer who lived in Ujjain was the son of Āditya Dasa. He is considered to be one of the nine jewels (Navaratnas) of the court of legendary king Vikramāditya (thought to be the Gupta emperor Chandragupta II Vikramāditya). Though little is known about his life, in one account he supposedly hailed from South Bengal, where in the ruins of Chandraketugarh there is a mound called the mound of Khana and Mihir. Khana was the daughter-in-law of Varāha and a famous astrologer herself. Modern Shakadvipi Brāhmaṇas, especially astrologers, regard Varāhamihīra as their ancestor, although there is no ancient documentary proof in favor of this belief.

FIGURE 7 VARĀHAMIHĪRA

WHERE AND WHEN DID HE LIVE

In order to decipher the period and the location where he lived, we have marshaled the following facts:
Rendered In English : Sapta – seven, dvi – two, Veda – four (makes 427), S saṇkhya¯- Reckoning or counting from , Ṡakakalam – Ṡaka era, Apasya – Having left , completed, chaitra – chaitra month, Ṡukla – the Brightening half of the lunar month, ādi – Beginning , primordial, arddhā - half, āstama – setting, bhānau – sun, Yavanapuri - the city of Yavanapuri, Saumya- Buddha – the planet mercury, Divasa - day Panchasiddhāntika.[276] I am indebted to the work done by M.L. Raja[277] in unearthing these important facts in his monograph on Āryabhaţa. Deduct the number of years 427 of the Ṡaka era elapsed, (i.e. deduct 427 from the number of years in Ṡaka era, for which we are calculating the Ahargana – the ahargana is analogous to the Julian day count at the beginning of the bright half of Chaitra , when the Sun has half set at Yavanapuri at the beginning of Wednesday. This means that Varāhamihīra compiled the Panchsiddhāntika in the 427th Year of the Ṡakanripa Kala. This leaves us the task of deciphering the beginning of the Ṡaka era. However, loosely speaking there are 3 Ṡaka eras which were in use during that time.

1. The first of these is the Ṡakanripa Kala year of King Kurash II (Cyrus) son of Kambujia (Cambyses) of the Āryamanush or Haxa Manish. In order to deduce this we need to refer to the other work that he wrote, the Bṛhat Saṃhitā, 3rd sloka of the 13th Adhyaya (Chapter).
2. The second of these is the Vikrama era.
3. The third of these is the Saptarisi era.

The Seven sages (Ursa Major – the Great Bear) were stationed in the Asterism Magha, when King Yudhistira was ruling the earth. The commencement of the Ṡaka era took place 2526 years after the regnal period of that monarch.

We know that Yudhishtira of the Pancha Pandava won the MBH war during (3101 + 36) and then ruled for 36 years up to 3101 BCE. Twenty five years after Kaliyuga began, when, Yudhishtira left the world in 3076 BCE. (The starting year of the saptarisi calendar or the Laukika or Kashmirabdham). The saptariṣi Mandalam was in the Magha constellation, as per the astronomical data, and *Varāhamihīra* states that the Ṡaka era he is referring to started 2526 years after this, which puts us at 550 BCE. So the Ṡaka era he was talking about must have been the Ṡakanripa kala of King Kuru (Kurush) of Persia. So now we are ready to determine the date that Varāha was talking about as being 550-427 = 123 BCE... The Ṡakanripa kala did not find much usage after the Persians lost control of the territories they had gained during the reign of Kurush. This sloka from the BrihatSaṃhitā is mentioned also in Kalhana's Rājataraṅgiṇi. The Rājataraṅgiṇi was written in 1148 CE. This

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[276] *Edited with Sanskrit Commentary. - and English Translation by G. Thibaut and Mahamahopadhyaya S. Dvivedi, Reprint, Motilal Banarsidas, 1930, reprint Cosmo publications,2002, 8th sloka of the first Adhyaya, page 4 of the English translation , pages in the book are not consecutively numbered*
[277] *Raja ML Āryabhaţa, 2764 BCE, Monograph, 2007*

quote occurs in the 56th sloka of the 1st Taranga. The confusion regarding the different Śaka eras was created by the British, by their hopeless mangling of the chronology starting with the misinterpretation of the Greek synchronism[278] where they concluded that Megasthenes was the ambassador to the court of King Chandragupta Maurya, whereas he was most likely an ambassador to the court of the Gupta Empire. According to the British chronology, the Vikrama Śaka is named after a King who was not yet born.

PANCHA-SIDDHĀNTIKA

Varāhamihīra's main work is the book *Pañchsiddhāntikā*, "[Treatise] on the Five [Astronomical] Canons. Gives us information about older Indian texts which are now lost. The work is a treatise on mathematical astronomy and it summarizes five earlier astronomical treatises, namely the Sūrya Siddhānta, Romaka Siddhānta, Paulisa Siddhānta, Vaśiṣţa Siddhānta, and Paitamaha Siddhāntas. It is conventionally believed to be a compendium of native Indian as well as Hellenistic astronomy (including Greek, Egyptian, and Roman elements). It is mainly an algorithmic guide to computation, estimating such things as the duration of eclipses based on the diameter of the moon and other relevant parameters. The techniques involved drew on methods that were established by Āryabhaṭa and then further developed by his followers in India such as Varāhamihīra and Brahmagupta."

THE 11TH CENTURY CENTRAL ASIAN SCHOLAR AL BIRUNI ALSO DESCRIBED THE DETAILS OF "THE FIVE ASTRONOMICAL CANONS":

They [the Indians] have 5 Siddhāntas:

- Sūrya-Siddhānta, i.e. the Siddhānta of the Sun, composed by Lāṭa,
  Vaśiṣţa.-Siddhānta, named after one of the stars of the Great Bear, composed by Vishnuchandra,
- Paulisa-Siddhānta, Occidentals assume based merely on Phonetic similarity that it was composed by a Greek named Paul but I think they are clutching at straws, especially if they cannot find the corresponding Greek or Latin text.
- Romaka-Siddhānta, Occidentals assume based merely on Phonetic similarity that it was composed by a subject of the Roman Empire, when in reality it was composed by Śrīsheṇa.
- Brahma-Siddhānta, so called from Brahma, composed by Brahmagupta, the son of Jishṇu, from the town of Bhillamāla between Multān and Anhilwāra, 16 yojanas from the latter place."

BRIHAT SAṂHITĀ

Varāhamihīra's other most important contribution is the encyclopedic Brihat Saṃhitā. *Varāhamihīra* also made important contributions to mathematics. He was also an astrologer. He wrote on all the three main branches of Jyotiṣa astrology:

1. Brihat Jataka - is considered as one the five main treatises on Hindu astrology on horoscopy.
2. Daivaigya Vallabha
3. Laghu Jataka
4. Yoga Yatra
5. Vivaha Patal
6. His son Prithuyasas also contributed in the Hindu astrology; his book "Hora Sāra" is a famous book on horoscopy.

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[278] *Vepa, Kosla The Pernicious Effects of the Misinterpreted Greek Synchronism in Indian history" Presented at the ICIH 2009, Available in Souvenir Volume of ICIH 2009*

WESTERN INFLUENCES

It is a facile assumption that Occidentals make based on phonetic similarity to the words Rome and Paul that the Romaka Siddhānta should be translated as the "Doctrine of the Romans" and the Paulisa Siddhānta should be regarded as the "Doctrine of Paul". But the Paulisa Siddhānta looks a lot like another Siddhānta of Indian origin, are written in Sanskrit and not in Greek, and talk about Yugas and time scales that are nowhere else to be seen in any Greek document of that vintage. The assertion that the Romaka and Paulisa are Greek or Roman (since when did Rome become a learned center of Astronomy?). In the absence of any evidence we will be constrained to regard this as mere speculation. So, it is legitimate to ask the question, what precisely they borrowed from the Greeks. Furthermore the author of the Romaka Siddhānta is frequently mentioned as one Srisena. It is assumed that his work is based on Roman rather than Greek sources. But there is no valid reason for doing so since there is no evidence that the Romans had anything to teach the Indians. A remark in the Brihat-Saṃhitā by *Varāhamihīra* says: "The Yavana, though impure, must be honored since they were trained in sciences and therein, excelled others".

Mleccha hi yavanah steṣu samyak Śāstramidamsthitam I
Rsivat tepi pujyante kim punar daivavid –dvijah II Brihat-Saṃhitā 2.15

But it is a definite leap in faith to assume he was equating Yavanas with Greeks, There are sufficient reasons as we have said already to assume that *Varāhamihīra* was not referring to Greeks when he was talking about Yavanas. See for instance http://www.scribd.com/doc/13298002/Yavanas-Are-Not-Greeks

SOME IMPORTANT TRIGONOMETRIC RESULTS ATTRIBUTED TO VARĀHAMIHĪRA

$\sin^2\theta + \cos^2\theta = 1$ (essentially the trigonometric form of the Baudhāyana-Pythagoras theorem)

$\sin\theta = \cos\left(\frac{\pi}{2} - \theta\right)$

$\sin^2\theta = \frac{1-\cos 2\theta}{2}$

He not only presented his own observations, but embellished them in attractive poetic and metrical styles. The usage of a large variety of meters is especially evident in his *Brihat Jataka* and Brihat-Saṃhitā. The Pañcha Siddhāntikā or Five Treatises is a compendium of various schools of Indian astronomy including the Ārya Pakṣa, Sūrya Pakṣa, and the Brahma Pakṣa. In 5 sections, his monumental work progresses through all aspects of Indian astronomy.[279]

VARĀHAMIHĪRA'S QUOTES ON ASTRONOMY

V mentions various aspects of astronomy that an astronomer should have command of, in order to qualify as an astronomer.

THE QUALIFICATIONS OF AN ASTRONOMER

- He must know the divisions of the heavens and the skies and of time, in ages, years, half years, seasons, months, and half months.
- He must know there are 4 kinds of months, solar, civil, sidereal, and lunar, and how it happens that there are added months and subtractive days.
- He must be able to explain in what respect the reckoning after solar time shows similarity or difference compared with lunar, sidereal and civil reckoning of time and to what use each of these is adopted or not. And when there is a discrepancy between the *Siddhāntas,* he must be able to prove experimentally, by means of the agreement between the shadow and the clepsydra, between

[279] *Sachau, Edward. C. Al Biruni's India (1910), vol. I, p.153.*

observation and calculation, at what moment the Sun has reached the solstitial point, at how many *ghatikas* the Sun enters the prime vertical.

- He must know the cause of the swift and slow motion, the northern and southern course and the moving mean epicycle of the Sun and other planets.
- He must tell the moment of commencement and separation, the direction, measure, duration, amount of obscuration, color, and place of the eclipses of the Sun and Moon, also the future conjunctions and hostile encounters of the nine planets.
- He must be skilful in ascertaining the distance of each planet from the earth expressed in *yojanas;* further the dimensions of their orbits and the distance of the places on earth in *yojanas.*
- He ought to be clever in geometrical operations and in the calculation of time in order to determine the form of earth, the cycle of the circuit of the asterisms etc., the depression of the pole, the diameter of the day, circle, the ascensional differences in time, the rising of the signs, the *gharikas* corresponding to the shadow of the gnomon and such like processes."

This is just to give an idea of the breadth of knowledge already mastered by the ancient Indic and is by no means a complete and exhaustive listing.

Varāhamihīra also expressed his views regarding the various debated questions of his time.

Regarding the shape of the earth, he wrote:
"All things which are perceived by the senses are witness in favor of the globular shape of the earth, and refute the possibility of its having another shape" Regarding the positions of the objects on the surface of the earth and its natural attractive power, he said, "Mountains rivers, trees, cities, men and angels, all are around the globe of the earth. And if Yamakoti and Rum (cities) are opposite to each other, one could not say, one is 'low' in relation to the other, since the 'low' does not exist. How could one say that one place of the earth is 'low', as it is in every particular identical with another place on earth and 'one place could as little 'fall' as any other. Everyone speaks of himself with regard to his own self. 'I am above and the others are below', whilst all of them are around the globe like the blossoms springing on the branches of a Kadamba tree. They encircle it on all sides, but each individual blossom has the same position as the other, neither the one hanging downward, nor the other standing upright. For the earth attracts that which is upon her; as it is the 'below' towards all directions and heaven is the 'above' towards all directions." Varāhamihīra, however, regarded the earth as an immovable sphere fixed at the centre of the universe, around which the sun, the Moon, and other planets revolved. If the earth had motion, he wrote, *"A bird would not return to its nest as soon as it had flown away from it towards west." In later times, Al Biruni expressed his opinion of Varāhamihīra as follows*: *"Varāhamihīra seems sometimes to side with the Brāhmaṇas to whom he belonged and from whom he could not separate himself. On the whole, his foot stands firmly on the basis of truth and he clearly calls out the truth."*

17. BRAHMAGUPTA (CONVENTIONAL DATING 598 CE)

Brahmagupta was one of the Galaxies of brilliant mathematicians that graced the Indian subcontinent over a period of several millennia. There is considerable doubt as to the date of Brahmagupta. More research needs to be done to clarify his date.
Apart from his astronomical contribution which were considerable he was the first to codify the rules of zero.
The sum of two positive quantities is positive 7 + 9 = 16
The sum of two negative quantities is negative -7 + (-9) = - 16
The sum of zero and a negative number is negative {a debt (debit) plus zero is a debt 0 + (-7) = -7
The sum of zero and a positive number is positive 0 + 9 =9
The sum of zero and zero is zero. 0+ 0 = 0

The sum of a positive and a negative is their difference; or, if they are equal, zero 7 + (-9) = -2
In subtraction, the less is to be taken from the greater, positive from positive 9 – 7 = 2
In subtraction, the less is to be taken from the greater, negative from negative - 7 – (-9) = 2
When the greater however, is subtracted from the less, the difference is reversed 7-9= - 2
A debt subtracted from zero is a fortune (credit) 0-(-7) = 7
A fortune subtracted from zero is a debt 0 – 7 = -7
When positive is to be subtracted from negative, and negative from positive, they must be added together, 7 – (- 9) =16
The product of a negative quantity and a positive quantity is negative, -7*9 = -63
The product of a negative quantity and a negative quantity is positive -7 * -9 = 63
The product of two positive, is positive. 7*9 = 63
The product of a zero multiplied by a debt or fortune is zero 0 * -8 = 0 * 8 = 0
Positive divided by positive or negative by negative is positive. 8/4 = -8/-4 = 2
Positive divided by negative is negative. Negative divided by positive is negative. 4/ (-2) = (-4)/2= -2
A positive or negative number when divided by zero is a fraction with the zero as denominator
Zero divided by a negative or positive number is either zero or is expressed as a fraction with zero as numerator and the finite quantity as denominator.
He is famous for many contributions and we cannot mention all of them in this volume.

THE CONTENTS OF BRAHMASPHUTA SIDDHĀNTA

1. On the nature of the Globe and figures of heaven and earth
2. On the revolutions of the Planets, on the calculation of time, i.e. how to find the time for different longitudes and latitudes; how to find the mean places of planets, how to find the Sine of an arc.
3. On the correction (true anomaly) of the places of the planet
4. On three problems; how to find the shadow, the elapsed portion of the day, and the *ascendants,* and how to derive one from the other.
5. On the planets becoming visible when they leave the rays of the sun (heliacal rising), and their becoming invisible when entering them (heliacal setting).
6. On the first appearance of the moon, and about her two cusps.
7. On the lunar eclipse.
8. On the solar eclipse.
9. On the shadow of the moon,
10. On the meeting and conjunction of the planets.
11. On the latitude of the planets,
12. A critical investigation for the purpose of distinguishing between correct and corrupt passages in the texts of astronomical treatises and handbooks.
13. On arithmetic; on plane measure and cognate subjects.
14. Scientific calculation of the mean places of the planets.
15. Scientific calculation of the correction of the places on the planets.
16. Scientific calculation of the three problems.
17. On the deflection of eclipses.
18. Scientific calculation of the appearance of the new moon and her two cusps.
19. On *Kuttaka* i.e. the algebra.
20. On the shadow.
21. On the calculation of the measures of poetry and on metrics.
22. On cycles and instrument of observation.
23. On time and the four measures of time, the solar, the civil, the lunar, and the sidereal.
24. About numeral notation in the metrical books of this kind.

In the *Brahmasphuta·siddhānta,* Brahmagupta deals with astronomy, algebra, arithmetic and geometry. 1, 2 He not only mentions his own original views and contributions on these subjects, but also compares them with those of the earlier mathematicians and the ones mentioned in the sources of Indic tradition such as the Purāṇa. So his work has a lot of historical interest also in these fields. We are forced to cut short the various contributions that Brahmagupta made for lack of space.

18. BHĀSKARA I. (CA.600 – CA. 680 CE)

Bhāskara I belonged to the first rank of Mathematicians of India. His most famous works are the Mahābhāskariya, the Laghubhāskariya, and a commentary Bhāṣya on Āryabhaţa.
Bhāskara I is the earliest known commentator of Āryabhaţa's works. His exact time is not known except that he was in between Āryabhaţa and Varāhamihīra".
Bhāskara I in his commentary to *Āryabhaţīya* mentions the following verse (Ch I verse 9):
Kalpadherabdhnirodhadhayam abdharashiritiritaha:
Khagnyadhriramarkarasavasurandhrenadhavaha: Te cangkkairapi 1986123730 |
"*Since the beginning of the current Kalpa, the number of years elapsed is this: zero, three, seven, three, twelve, six, eight, nine, one (proceeding from right to left) years. The same (years) in figures are 1986123730*".
Kalpadherabdhanirodhat gatakalaha:
Khagnyadhriramarkarasavasurandhrenadhavaha: Te ca 1986123730.

Bhāskara mentions the names of Latadeva, Nisanku, and Panduranga Svami as disciples of Āryabhaţa. But he does not say that any of these were his Gurus. Bhāskara also refers to the fact that much time has elapse between him and Āryabhaṭa, whereas in reality, if we believe the conventional dating there is merely a gap of sixty years, which could easily be bridged by one person. The entire question of the conventional dating of Āryabhaṭa, Varāhamihīra and Bhāskara I needs to be reexamined. Furthermore, even though he is a contemporary of Brahmagupta he never mentions him.
The contents of the Mahābhāskariya are as follows,

Mean longitudes of the planets and planetary pulverizer
The Longitude correction
Direction, Place and Time. Conjunctions of the planets with each other and with Junction stars in the zodiacal asterism
Longitude of a Planet
Eclipses of the sun and the moon
Rising, Setting and conjunction of Planets
Astronomical Constants
Examples

The Laghubhāskariya is an abridged version of the Mahābhāskariya. The great popularity of Bhāskara's work is attested to by the number of commentaries that have been written.

19. LALLĀCHARYA 700 CE SON OF BHATTA TRIVIKRAMA

An equally well known text is **Śiṣyadhīvriddhida (SDN)** ***of*** Lalla-with commentary of Mallikārjuna Sūri, Critical Edited and Translated, Math including notes and Indices in 2 parts by **Bina Chatterjee**, INSA. New Delhi, 1981.
Śiṣyadhīvriddhida – Tantra of Lallācharya, literally means a Treatise for increasing the Intelligence of students. He is mentioned by Śripati in the mid 11th century and appears to emulate the style of Āryabhaţa.

Clearly the title suggests that the ancient Indic did not believe that intelligence was merely an inherited trait and that by training in epistemology, logic, etymology, Grammar and the facility with which past accumulated knowledge could be mastered one could enhance the natural abilities of the student. All had a part to play in determining the intellectual effectiveness of an individual. The SDV is undoubtedly one of the greatest books of ancient India dealing with the subject of Astronomy and Mathematics written about 1300 years ago. Here with we are presenting the contents of the English translated version of the *Śiṡyadhivrddhīda – Tantra* of Lallacharya.

Contents:

- Revolutions of the planets
- Lunar and Solar days
- Civil and Sidereal days
- Civil days of the Planets and Lunar months
- Intercalary Months and Omitted Tithis
- Planetary conjunctions and Revolutions of the apogee
- Calculation of days elapsed
- Mean longitudes of planets
- Alternate method for Mean longitude
- Calculation of Suddhi
- Diameter of the Earth's shadow in yojanas
- Angular diameter of the Sun etc.
- Data from computing the Solar eclipse
- Download free e-book on_SISYADHIVRDDHIDA – TANTRA OF LALLACARYA

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20. DEVĀCHĀRYA, SON OF GOJANNA (FL.689 CE) CESS, 3.121

He wrote the Karaṇaratna, which has 8 chapters and 254 verses. As the name indicates this is intended as a Manual or Handbook to facilitate computation... The zero point of the epoch was adopted by Devāchārya to synchronize with the beginning of Chitra in the year Śaka 611. He was an avid follower of AB and maintains that "having taken a deep plunge in the ocean of Aryabhata-Śastra I have brought out this Jewel called Karaṇaratna. This edition was edited with an English translation by K.S. Shukla. He calculated the epoch date for computation of Ahargana (the number of days elapsed since the beginning of the Saka year 611) which corresponds to 689 CE. He flourished 60 years after Bhāskara I wrote his commentary on Āryabhaţīya and 24 years after Brahmagupta wrote his Khandakhādyaka.

21. SRIDHARĀCHĀRYA, FL. C. 750

Sridhara, (flourished c. 750, India), highly esteemed Hindu mathematician who wrote several treatises on the two major fields of Indian mathematics, *Pati-Gaṇita* ("mathematics of procedures," or **algorithms**) and *BijaGaṇita* ("mathematics of seeds," or equations). Sridhara (c. 870-930), who lived in Bengal, wrote the books titled *Nav Śatika*, *Tri Śatika* and *Pātī Gaṇita*. He gave:

- A good rule for finding the volume of a sphere
- The formula for solving quadratic equations.
- The *Pati Gaṇita* is a work on arithmetic and mensuration. It deals with various operations, including
- Elementary operations
- Extracting square and cube roots
- Fractions
- Eight rules given for operations involving zero
- Methods of summation of different arithmetic and geometric series, which were to become standard references in later works.

Very little is known about Sridhara's life. Some scholars believe that he was born in Bengal, while others believe that he was born in South India. All three of Sridhara's extant works—the partially preserved *Pati Gaṇita*, *Gaṇitasara* ("Essence of Mathematics"), and Gaṇitapancha-*vimashi* ("Mathematics in 25 Verses")—belong to *Pati Gaṇita*, but, according to **Bhāskara II** (1114–c. 1185), he wrote at least one book on *Bija Gaṇita.*

22. SUMATI OF NEPAL (800 CE)

Sumati of Nepal wrote the Sumatitantra, which is a tantra. Its six ways of calculating ahargana (literally, total number of mean civil days elapsed since the beginning of the Kali) begins from the start of the Kali Yuga, expressing the expired years of the Kali as "Bhavisya sampravaksami kalikanca yathakramam"
i.e. "introducing the future Kali years in a sequence."
The Sumatitantra gives an R- Sine Table with 90 divisions of a quadrant, one for each degree of the arc. It is sometimes accurate up to the 12th decimal place (e.g., 889 for 15^{o}], 1790 for 30^{o}, 2431 for 45^{o}" 2977 for 60[degrees]) whereas for other degrees the text only gives round figures by ignoring decimal points lower than 0.50, (e.g., 3321 for 75 [degrees]). Most classics on Indian astronomy dated before Vatesvara (b. 800 CE) give 24 Sines for a quadrant, with the value of Radius= 3438. This is so in Paitamaha Siddhanta, Aryabhata I, Brahmagupta, Lalla, and modern Sūrya-Siddhānta. The Sines for Other degrees can, of course, be derived on the basis of the 24 Sine tables, and smaller decimal points are inevitable if lesser arcs are taken as units. Varāhamihīra, on the other hand, gives Sines for a radius of 120 with 225" seconds as interval. As the table differs from all others, including the one given by Varāhamihīra, the text of Sumatitantra seems to be redacted with interpolations by later hands.

23. GANAKA OR KANAKA (773 CE) THE FIRST TRANSMITTER TO THE ARABS

There are tantalizing references to the identity of the man who presented himself before Khalīf Al Mansur (but not much more), who was reputedly skilled in the calculus of the stars known as Sindhind (e.g. Siddhānta) and possessed methods for solving equations founded on the kardagas (?) (Kramajya) sines, calculated of every half degree, also methods for computing ellipses, and other things. Al Mansur ordered the book in which all this was contained to be translated into Arabic, and that work must be prepared from it which would serve as a foundation for preparing the motion of the planets. Thus it was that the legendary Indic prowess in creating algorithms wound its way to the west and gave birth to the series of great astronomical works in the Islamic world called Zij (a combination of an Ephemeris and a Karana text).

24. GOVINDASVĀMIN (800-850 CE) OR GOVINDASWAMI

Govindasvāmi (or Govindasvāmin) was an Indian mathematical astronomer whose most famous treatise was a commentary on the Mahābhāskariya of Bhāskara I wrote the in about 600 A. D. It is an eight chapter work on Indian mathematical astronomy and includes topics which were fairly standard for such works at this time. It discussed topics such as the longitudes of the planets, conjunctions of the planets with each other and with bright stars, eclipses of the sun and the moon, risings and settings, and the lunar crescent. Govindasvami wrote the Bhāsya in about 830 which was a commentary on the Mahābhāskariya. In Govindasvāmi's commentary there appear many examples of using a place-value Sanskrit system of numerals. One of the most interesting aspects of the commentary, however, is Govindasvāmi's construction of a sine table. Indian mathematicians and astronomers constructed sine table with great precision. They were used to calculating the positions of the planets as accurately as possible which in turn needed the sine table with a high degree of accuracy. Govindasvāmin considered the sexagesimal fractional parts of the twenty-four tabular sine

differences from the Āryabhaţīya using the equivalency of what we would refer to today as Newton Gauss Interpolation formula. The Govindasvamin values are given in Table of Chapter He wrote the following
Govindakṛti, **CESS** 2, 143; **KVS**, 28
Govindapaddhati, **CESS** 2,143**, KVS**, 28

25. ŚANKARANĀRĀYAṆA (825 -875)

Śankaranārāyaṇa of Quilon, in Kerala, rose to eminence through his commentary on Laghubhāskriya, the Sankaranārāyanīyam and later appointed chief court astronomer of King Ravi Varma Kula Śekhara of the Cera dynasty of Kerala. He quotes a verse from Āchārya Sumati in his Vivārana on Laghubhāskariya (CE 869), in connection with lunar and solar eclipses, ten years before the so-called Manadeva Samvat 304. He made a reference to the solar eclipse watched by the King and himself on the 1449066th day of the Kaliyuga in the afternoon.

26. MAHĀVĪRA (CA. 810 – 870)

Mahāvīra was a Jaina mathematician who lived in what is current day Karnataka. His original contribution was in the area of permutations & combinations. His pedagogical skills are considerable as evidenced by his famous book the *Gaṇita Sara Samgraha*, dated 850 CE, which was designed as an updating of Brahmagupta's book. To quote Jean Filliozat[280]"This book deals with the teaching of Brahmagupta but contains both simplifications and additional information." Although like all Indian versified texts, it is extremely condensed, this work, from a pedagogical point of view, has a significant advantage over earlier texts. It consists of nine chapters and includes all mathematical knowledge of mid-ninth century India. It provides us with the bulk of knowledge which we have of Jaina mathematics and it can be seen as in some sense providing an account of the work of those who developed this mathematics. There were many Indian mathematicians before the time of Mahāvīra but, perhaps surprisingly, their work on mathematics is always contained in texts which discuss other topics such as astronomy. The *Gaṇita Sara Samgraha* by Mahāvīra is the earliest Indian text which we possess which is devoted entirely to mathematics. This indicates that Mathematics is by then considered to be an independent discipline in the introduction to the work Mahāvīra paid tribute to the mathematicians whose work formed the basis of his book. These mathematicians included Aryabhata I, Bhāskara I, and Brahmagupta. Mahāvīra writes:
With the help of the accomplished holy sages, who are worthy to be worshipped by the lords of the world, I glean from the great ocean of the knowledge of numbers a little of its essence, in the manner in which gems are picked from the sea, gold from the stony rock and the pearl from the oyster shell; and I give out according to the power of my intelligence, the Sara Samgraha, a small work on arithmetic, which is however not small in importance.

27. CHATURVEDA PRTHUDAKASVAMIN (FL. 850)

Chaturveda Prthudakasvami (fl. 850), commentary on Brahma Sphhuta Siddhānta **, "**Just as grammarians employ fictitious entities, such as Prakrti, pratyaya, Agama, lopa, vikāra, etc to decide on the established real word forms, and just as Vaidyas employ tubers to demonstrate surgery, one has to understand and feel the content that it is in the same way that the astronomers postulate measures of the earth etc., and models of motion of the planets in Manda and Śīghra-pratimandalas for the sake of accurate predictions "
In other words his admonition to us is that, a Model is a representation of reality but not reality itself. Do not get enamored of your model (as the Greeks did by making uniform angular velocity fundamental principle in

[280] *Filliozat, Jean, La science indienne antique, in* R Taton (ed.), Histoire générale des sciences *(Paris, 1957-1964), 159-.*

the Ptolemaic models). We do not know of course whether he was referring specifically to the Greeks when he made this comment.

TABLE 4 THE NINE CHAPTERS OF THE GAṆITA SARA SAMGRAHA
1. Terminology
2. Arithmetical operations
3. Operations involving fractions
4. Miscellaneous operations
5. Operations involving the rule of three
6. Mixed operations
7. Operations relating to the calculations of areas
8. Operations relating to excavations
9. Operations relating to shadows (applicable to Gnomons)

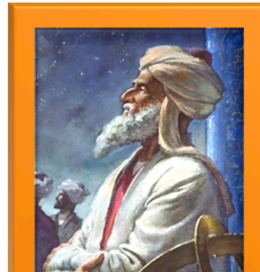


FIGURE 8 AL - BIRUNI



28. VATESVARA FL.904 B. CA. 880

Vatesvara was the son of Mahādatta, a resident of Ānandapura. He says that he was born in Śaka Era 802 and that he was 24 years old (Śaka Era 826) when he wrote the Vatesvara Siddhānta. (See: How many kinds of Śaka s (Eras) are there?)

He belonged to a city called Ānandapura. This was wrongly identified as Mākhovāl, in Punjab, which got the name Ānandapura only in 1664 CE. Based on the 34^{d} 9^{m} latitude he gives, which is close to the latitude of Srinagar and based on the fact that Nagarapathari (lat 33^{d} 55^{m}), might be Nagarapura, the place of Vatesvara's birth, Rai concludes that Vatesvara must be a Kashmiri, named after Vatesvara (Siva), worshipped by Kashmir's Ravana. Reputed for 2 publications Karana Sara, a Karanagrantha. Epoch of Śaka 821 = 899 CE. Often quoted by Al Biruni in both his India and in his al Qānūn al Masūdī Vatesvara Siddhānta composed when he was 24 years old, i.e. in 904 CE, corrected and supplemented by Govinda. The 8 adhikaras of the Gaṇita section are Madhyagati Mean anomaly

Sphuṭagati True anomaly
Tripraśna – direction, place and time
Chandra Grahaṇa – the stations of the Moon
Ravigrahaṇa – the motion of the Sun
Udayāstmaya
Rńgonnati
Samāgama

Year of the Karanagrantha referred to by Vatesvara is 821 Śaka Era. (See: *Varāhamihīra* – Really 427 of Śaka Era?: Panch Siddhantika – *Varāhamihīra* referred to a Karana Grantha Year of 427 Śaka Era). In this case also, Al Biruni assumed that the year of the Karanagrantha referred to was the year of composition of the Karanasara and this was incorrect as per Sri Rai.

29. MUNJĀLA OR MANJULA (FL 932)

Mostly he is referred to as Manjula, except in the Andhra country where is referred to as Munjāla. The motion of the moon has always been considered a difficult problem and Ptolemy had a great deal of difficulty with the lunar model and was probably his largest error. The moons motion around the earth and was not fully understood in the west until the early 20th century. Ptolemy constructed an ingenious geometric model of the moon's orbit which was capable of predicting the lunar ecliptic longitude to reasonable accuracy. Unfortunately, this model necessitates a monthly variation in the earth-moon distance by a factor of about two, which implies a similarly large variation in the moon's angular diameter. However, the observed variation in the moon's diameter is much smaller than this. Hence, Ptolemy's model is not even approximately correct. Manjula described the term causing evection and Bhāskara II described the term that signifies Variation.

The precession of the equinoxes which causes the shifting of the pole star with time was described by Manjula. He gave a value of 59.2" per year while Chandraṡekhara Sāmanta in the nineteenth century gave 47.179", which is pretty good considering all his measurements were made by naked eye.

His works include:

Laghumanasa (CESS, 4, 435-436)
A critical study of the Laghumānasa, KS Shukla, INSA, New Delhi, 1990
Commentary on the Laghumānasa of Munjāla. CESS 4 227-228; INSA 172

28. ĀRYABHAṬA II (FL 950)

AB II is known for his astronomical treatise, the Mahāsiddhānta, CESS1.53-54, 2.15-16; 4-28, INSA 10-11, Edited with his own commentary by Sudhākara Dvivedi, Benares Sanskrit series, Benares, 1910, Ed. With translation by SR Sharma, Pūrva Gaṇita, 2 parts, Erich Mauersberger, Marburg, 1966. He discusses mainly indeterminate equations of the first degree. He improves upon the method by suggesting a shorter procedure.

29. BHATTA UTPALA (BHATOTPALA) (FL.966- 969)

Bhatta Utpala of Kashmir wrote:

- a commentary on Sūrya Siddhānta.
- a large number of commentaries on the works of *Varāhamihīra*
- and others as well as independent treatises on his own.

Three of his commentaries have verses at the end indicating the dates on which they were composed. His commentary on the Bṛhat Saṃhitā is widely used.

30. AL BIRUNI (973 – 1050 CE)

Al-Biruni, Abu al-Raihān Muhammad bin Ahmad wrote the book on his Ta'rikh al-Hind ("chronicles of India"). While Al Biruni was not Indian we have included him in this list since he was a keen observer and spent close to 30 years in India chronicling his impressions on all aspects of life in India. Al Biruni was born 973 CE in

Khwarezm, modern Khiva and after the conquest of the area by Mohammad of Ghazni was brought to Ghazni along with a number of other earned men in 1017 CE. He was familiar with a great deal of literature on India, prior to coming to India. In India he stayed at different places, studied the sacred books, science and philosophy presumably after mastering Sanskrit. He studied the society, customs, and manners, geography, with the help of Indian scholars and wrote his magnum opus Kitāb ul Hind on India[281]. A considerable portion of the work is devoted to matters Astronomical. His work on India is a profound anthropological work, "one of the most scientific and objective studies of man and society made in the medieval era". It formed the basis of Ibn Khaldun's famous work the Prolegomena and his general observations on human history.

Al Biruni referred to the works of many ancient Indian mathematicians and astronomers. Karana Sara of Vaţeŝvara is one of those books, which was not available in India to the knowledge of this author in 1970. A book by Vaţeŝvara called Vaţeŝvara Siddhānta has been partially recovered and published in India. He was a follower of Āryabhaţa. His astronomical constants mostly agree with Āryabhaţa and he refutes Brahmagupta the way Brahmagupta criticized Āryabhaţa.

31. SRIPATI, SON OF NAGADEVA FL.1039

Ŝripati was a Jaina astronomer mathematician. He wrote Gaṇita tilaka, Dhikoti (1039 CE), Dhruvamanasa (1056 CE), and Siddhānta Ŝekhara and Bija Gaṇita in additon to 3 other works on astronomy and Astrology. The Gaṇita Tilaka is devoted exclusively to Arithmetic. The Siddhānta Ŝekhara is a work mainly on Astronomy in twenty chapters, and also deals with Algebra in 2 chapters namely Vyakta Ganitādyaya and Vyakta Ganitādyaya.

Ŝripati based many of his works on Brahmagupta, but was also influenced by Prthudaksvamin.

32. BRAHMADEVA GANAKA (FL.1092 CE)

Brahmadeva has contributed an astronomical book called the Karanaprakāsa. It consists of 10 chapters describing methods of calculating longitudes and latitudes. It quotes profusely from the work of Lallāchārya and Āryabhaţa.

33. SATANANDA (FL 1099 CE)

Satananda, end of 11th century, wrote calendrical work Bhaswāti, based on Varāhamihīra's Sūrya- Siddhānta. References of all astronomical measurements are given from his birthplace Puri in Orissa.

[281] Edited and translated by Edward C Sachau, as Alberuni's India 2 volumes, reprinted by London, 1879

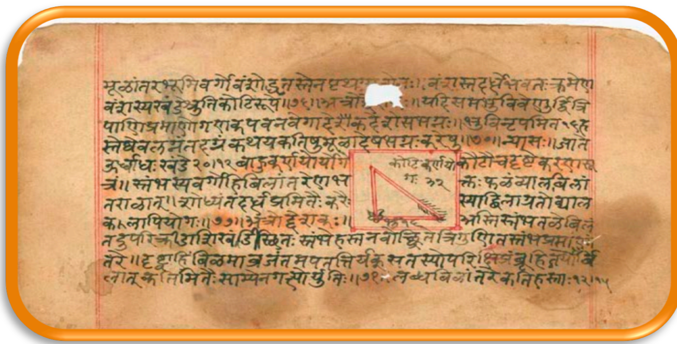


TABLE 5 A COMPARISON OF THE LĪLĀVATI AND A RANDOMLY CHOSEN FRENCH TEXT TITLED L'ARITHMETIQUE BY A JACQUES PELETIER IN1552

C	S	Sūtra	the *Līlāvatī* by Bhāskara	Peletier, *l'Arithmetique*, 1552	Bk; Ch
II	II	10-11	Numeration	Diffinition de Nombre	1; 1
		12-13	Rule of addition and subtraction	De l'Addition / Souztraction des nombres Entiers	1; 3,4
		14-16	Rule of multiplication	De la multiplication des Entiers	1; 5
		17	Rule of division	De la Division des Entiers	
		18-20	Rule for the square of a quantity	De l'extraction de la Racine Quarre	3; 1
		21-22	Rule for the square root		
		23-26	Rule for the cube	De l'extraction des racines cubiques	3; 3
		27-28	Rule for the cube root		
	III	29-30	Simple reduction of fractions	Reduction de diverses Fractions	2; 6
		31-32	Reduction of subdivided fractions	Des Fractions de fractions et de la reduction dicelles	2; 2
		33-35	Rules of quantities increased or decreased by a fraction	La maniere de valuer les Fractions denommees de quelque espece	2; 5
		36-37	Rule for addition and subtraction of fractions	De l'Addition des Fractions De la Souztraction des Fractions	2; 8 2; 9
		38-39	Rule for multiplication of fractions	De La Multiplication des Fractions	2; 10
		40-41	Rule for division of fractions	De la Division des Fractions	2, 11
		42-43	Rule for involution and evolution of fractions		
	IV	44-46	Cipher [rules for zero]		
III	I	47-49	Rule of inversion		
	II	50-54	Rule of supposition [regula falsi]	De la Regle de Faux de deux Positions	4; 6
	III	55-58	Rule of concurrence		
	IV	59-61	Problems concerning squares		
	V	62-69	Rule for assimilation of the root's coefficient		
	VI	70-73	Rule of three terms	De la Regle de Trois	1; 8
		74-78	Rule of three inverse	De la Regle de Trois Everse	1; 9
		79-84	Rule of compound proportion	De la Regle de 6 Quantitez	3; 20
		85-86	Rule of barter		
IV			Investigation of mixture	De la Regle d'Alligation	4; 4
	I	87-93	Interest		
	II	94-95	Fractions [cistern problem]	Aucune questions diversement	4; 10
	III	96-98	Purchase and sale	De la Regle Double	4; 1
	IV	99-100	A present of gems		
	V	101-109	Allegation	De la Regle d'Alligation	4; 4
	VI	110-114	Permutation & combinations		
V			Progressions	De la Progression des Entiers	1; 7
	I	115-126	Arithmetical progressions		
	II	127-132	Geometrical progressions		

34. BHASKARACHARYA OR BHASKARA II (1114-1185)

Bhāskara (also called Bhāskara II or Bhāskarāchārya, this latter name meaning "Bhāskara the Teacher".) may have been the greatest of the Hindu mathematicians. He has to his credit numerous achievements in several fields of mathematics including some that Europe wouldn't learn until the time of Euler. Until the advent of

FIGURE 9 THIS PAGE FROM THE LĪLĀVATI GIVES ANOTHER ILLUSTRATION OF THE PYTHAGOREAN THEOREM.

Bhāskara II there was no distinction made between an Astronomer and a Mathematician, because the main applications of the Mathematics were in Astronomy. Bhāskara II was the first of the Indic mathematicians to concentrate more on Mathematics rather than on Astronomy. His textbooks dealt with many matters, including solid geometry, combinations, and advanced arithmetic methods. He was also an astronomer. It is sometimes claimed that his equations for planetary motions anticipated the Laws of Motion discovered by Kepler and Newton. In algebra, he solved various equations including 2nd-order Diophantine, quartic Brouncker's and Pell's equations. His "Chakravala method," an early application of mathematical induction to solve 2nd-order equations, has been called "the finest thing achieved in the theory of numbers before Lagrange." (Earlier Hindus, including Brahmagupta, contributed to this method.) In several ways he anticipated calculus: he used Rolle's Theorem; he may have been first to use the fact that $d\sin x = \cos x \cdot dx$; and he once wrote that multiplication by **0/0** could be "useful in astronomy." In trigonometry, which he valued for its own beauty as well as practical applications, he developed spherical trigonometry and was first to present the identity: $\sin(\alpha+\beta) = \sin\alpha \cdot \cos\beta + \sin\beta \cdot \cos\alpha$

Bhāskara's achievements came centuries before similar discoveries in Europe. It is an open riddle of history whether any of Bhāskara's teachings trickled into Europe in time to influence its Scientific Renaissance. It speaks more of the Eurocentricity of the Occidental that not a single mathematician west of the Bosphorus has admitted that there is more than a finite probability that this took place. According to Bhāskara's own statement towards the end of his Golādhyaya, he was born in Śalivāhana Śaka 1036 or 1114 CE. He also adds that he came from Vijjadavida near the Sāhyadri Mountains. This place is identified with modern Bijapur in Mysore or current day Karnataka. S B Dikshit is of the opinion that Bhāskara II's original home was Paṭaṇa (in Khandesh), where a relevant inscription was found by Bhao Dhaji in 1865. According to the inscription, Manoratha, Mahe Śwara, Lakshmidhara, and Changadeva were the names of the grandfather, the father, the son, and grandson respectively of Bhāskara II. Cangadeva was The Chief Astronomer in the court of King Singhana and had established a Matha (residential learning institution) for the study of the works of his grandfather. Bhāskara's father Maheśwara was also his teacher. Brahmagupta was Bhāskara's role model and inspirer.

To Brahmagupta he pays homage at the beginning of his *Siddhānta-Ṣiromani* and most of his astronomical elements are taken from the *Brahmasphuta Siddhānta* or the *Rajamrganka* belonging to the same school. Bhāskara improved upon him not through any great original contribution but by the thoroughness with which he could and did analyze the rationale of the calculations. Bhāskara's exhaustiveness was so profound that his works have not only eclipsed lesser works but even the works of his great master Brahmagupta himself. Bhāskara is known for his two main works: a 'Siddhānta' text, the '*Siddhānta-Ṣiromani*' and a 'Karana' text, the '*Karanakutuhala*'. The former is a large text divided into four parts, namely *Pati Gaṇita or Līlāvati*, *Bija Gaṇita*, *Graha Gaṇita*, *and Goladhyaya*. Of these, the first two are usually treated as separate treatises.

The *Līlāvati* deals with arithmetic and geometry. There is a story which says that Bhāskara put to use all his astrological knowledge to find out an auspicious moment for her marriage, and on the marriage day had a water-clock fixed up as to hit the exact time favorable for her happy marriage, but his efforts were foiled by the child-bride herself. Impelled by girlish curiosity she kept on running to the water-clock and bending to peer at it. In one of these visits to the water-clock, a pearl loosened from her neck and got stuck to the hole of the water-clock. The auspicious moment passed unnoticed and the girl had to remain unmarried. To console her and perpetuate her name Bhāskara called his treatise on arithmetic and geometry by her name. According to others, *Līlāvati* was the name of Bhāskara's wife. More probably Bhāskara was attracted by this fanciful name. Bhāskara was known not only for his mathematical scholarship, but also for his poetic inclinations. A complete treatment of his work would need several chapters. The reader will have to await my next project the Encyclopedia of Mathematics and Astronomy.

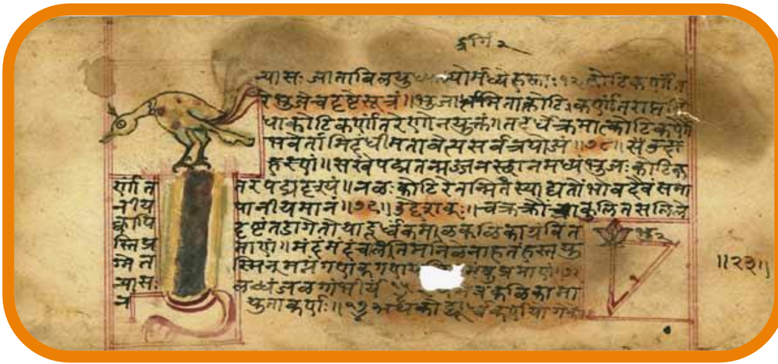
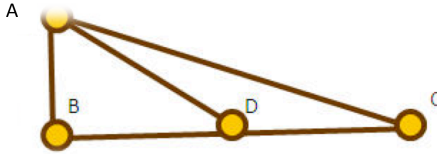


FIGURE 10 THIS IS A PAGE FROM A MANUSCRIPT OF THE LĪLĀVATI OF BHASKARA II (1114-1185) REFERRING TO THE SNAKE AND PEACOCK PROBLEM. THIS MANUSCRIPT DATES FROM 1650.

The rule for the problem illustrated here is in verse 151, while the problem itself is in verse 152:
Verse 151: The Square of the pillar is divided by the distance between the snake and its hole; the result is subtracted from the distance between the snake and its hole. The place of meeting of the snake and the peacock is separated from the hole by a number of HASTAS equal to half that difference.
To determine BD= l, given, AB = h and BC= d, and AD =DC, solution l = ½ (d – h^2/d)

Verse 152: There is a hole at the foot of a pillar nine HASTAS high, and a pet peacock standing on top of it. Seeing a snake returning to the hole at a distance from the pillar equal to three times its height, the peacock descends upon it slantwise. Say quickly, at how many hastas from the whole does the meeting of their two paths occur? (It is assumed here that the speed of the peacock and the snake are equal.)



The apocryphal story is that the text as named after his daughter Līlāvati, who was according to her horoscope to remain unmarried. According to others, *Līlāvati* was the name of Bhāskara's wife. More probably Bhāskara was attracted by this fanciful name. Bhāskara was known not only for his mathematical scholarship, but also for his poetic inclinations. A complete treatment of his work would need several chapters. The reader will have to await my next project the Encyclopedia of Mathematics and Astronomy. That Bhaskara's works were well known in Europe is demonstrated by Table 5[282] where the author (Albrecht Heeffer) compares the contents of a randomly chosen arithmetic or algebra book by a Jacques Peletier. The virtual identity of the table of contents of the Līlāvati, written roughly in 1150 CE with the contents of a randomly chosen French text, authored by Jacques Peletier[283] of the 16th (1552 CE) century, indicates a direct connection between the two. It appears more than likely that Peletier had a French translation of Līlāvati available. But that is not the impression that Eurocentric descriptions give of the development of Mathematics in 16th century Europe. They mention Al Khwarismi but hardly mention India as the source of most of the arithmetic. It is possible that Monsieur Peletier did not even know that there was such a close one to one correspondence in most of the chapters, as the mention of the source was quickly obliterated during the transmission in the chain between the Bhāskarāchārya of 1150 CE and *L'arithmetique de Jacques Peletier du Mans* (1552), The table 5 reproduced here is from Chapter IV of the PhD thesis of Albrecht Heeffer.

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[282] *Heeffer, Albrecht titled 'The tacit appropriation of Hindu Algebra in Renasissance Practical arithmetic'. This is Chapter IV of his PhD thesis. Gaṇita Bhāraṭi, vol. 29, 1-2, 2007, pp. 1-60.*
[283] *Peletier, Jacques - L'arithmetique. Parigi, Marnef, 1552*

35. MALAYGIRI (1150-1175) CESS, A, 4, 359

A Commentator on Jaina Works. Wrote the following, A vritti on Kshetrasamasa of Jinabhadra (609 CE). In fact we know of the original works only through the commentaries. A vritti on Chandraprajnāpati (CESS 4,360). A vritti is an exhaustive elaboration or explanation. It is more pedagogical in nature

THE SURI 'S AND OTHERS OF THE TELUGU SPEAKING REGION
HEMACHANDRA SŪRI (B. 1089)
PAVULURI MALLANA (11th Century, 1118-1191 CE)
MALLIKĀRJUNA SŪRI (1178)
SŪRYADEVA YAJWAN (1191)
MADANA SŪRI
MAHENDRA SŪRI (1292 - 1370)
GUṆARATNA SŪRI (FL. CA. 1375 CE)
ALLANARYA SURI CE
VIRUPAKṢA SURI
YALLAIYA (1482 CE)

There is one other school of astronomy in India which does not get the same publicity as the Kerala School but is nevertheless very important for its contributions to the continuity of the Indic civilization and these are the Sūri's of the Telugu region. Astronomical knowledge was widely prevalent throughout the recorded history of the Telugu speaking regions of the subcontinent. In this it was not substantially different than the other regions of the country. But a substantial number of works have been preserved in the Telugu script which was often used by the cognoscenti in order to ensure greater dissemination and this is why these are significant.

36. SŪRYADEVA YAJWAN (1191)

One of these about whom we know a fair amount is Sūryadeva Yajwan. In his different works, the name of Sūryadeva is suffixed with the surname Sūri, Yajwan, or Somasut. For example Sūryadeva Yajwan's work which he termed the Bhatta Prakāṣika of Āryabhaṭīya is a case in point. Sūryadeva was a resident of Gangapuri or Gangaikonda Cholapuram.
While the term Sūri indicates a high degree of scholarship, the other 2 terms indicate he had performed the Soma sacrifice (soma – yagna). He was a Brāhmaṇa of the Nidruva Gotra. It is important to know the Gotra because it would reveal whether there were a predominant number of indivduals belonging to this Gotra in this parampara as it would indicate a high degree of homogeneity within this parampara.

37. YALLAYA

Wrote a Supplement to the commentary of Sūryadeva Yajwan. He justifies his supplement with the following words "Since the commentary of Suryadeva, a master of the science of words, is brief", he suggests that wherever Suryadeva is brief, he will add alternate illustrative examples. Yallaya is a native of Skandasomeṣwara. Yallaya is the author of at least 5 more works.

Ganita Saṅgraha
Jyotiṣa darpana,
Kalpavali, a commentary on Surya Siddhānta
Kalpalata, an extensive commentary on the Laghumānasa of Manjula
A commentary in Telugu on the Sūrya Siddhānta.

Sūryadeva supplies us direct evidence of his date of birth. He clearly states that he was born in the (Ṡālivāhana) Ṡaka year 1113 (= 1191 CE). It must be borne in mind that throughout the Andhra country, use of the Ṡālivāhana Ṡaka year was prevalent. Elsewhere in the same work he states that he was born on Monday (Somvara) on the third Tithi of the dark half of the month of Māgha in Ṡaka year 1113.
MALLIKĀRJUNA SURI wrote a commentary vyākhyā on the Sūrya Siddhānta also in the twelfth century. **ALLANĀRYA SŪRI**, wrote a commentary on the Sūrya Siddhānta in Telugu, available at the Government Oriental Manuscripts Library, Chennai.

38. MĀDHAVA OF SAṆGAMAGRĀMA (C. 1340–1425)
BORN AS IRINNGARAPPILLY MĀDHAVA NAMBOODIRI

In the 19th century, the prevailing belief among the historians of science was that Mathematics and Astronomy in the Indian subcontinent had gone into hibernation after Bhāskarāchārya in the 12th century. The credit for demonstrating to the Occident that this was not so, must surely go to Charles M Whish, Esq., a civil servant in the East-India Company. In 1832 he brought to the attention of the historians the magnificent achievements of the Kerala School which flourished from the 14th to 17th century[284]. Among the major figures of this school are Mādhava (1350-1410) of Saṉgamagrāma, Parameṣvara (1360-1455), Nīlakaṉţa Somayājī (1444-1545) and Jyeṣţhadeva (c.1500-1600) whose significant contributions to mathematics include infinite series expansions of trigonometric functions and very accurate approximations to π.
Mādhava was the founder of the Kerala School of astronomy and mathematics, the illustrious Kerala astronomers. He was the first to have developed infinite series approximations for a range of trigonometric functions, which has been called the "decisive step onward from the finite procedures of ancient mathematics to treat their limit-passage to infinity". His discoveries opened the doors to what has today come to be known as mathematical analysis. As such he should be regarded as one of their earliest founders of Mathematical analysis One of the greatest mathematician-astronomers of the Middle Ages, Mādhava contributed to infinite series, calculus, trigonometry, geometry and algebra. Mādhava, lived at Irinjālakkuda, at that time known as Iringattikudal in Thrissur district, near Kochi in Kerala, between the years 1340 and 1425. Sanskrit scholars used to call the town as Saṉgamagrāmam, taking into consideration of the meaning of Kudal appearing in Iringattikudal, which has the meaning Sangam in Sanskrit. His works include
1. Sphutachandrāpti
2. Venvāroha
3. Agaṇitagrahachara
It is possible that he wrote Karana paddhati, a work written sometime between 1375 and 1475
Nīlakaṉţa attributes the series for Sine to him. It is not known if Mādhava discovered the other series as well, or whether they were discovered later by others in the Kerala School.
Mādhava's discoveries include the Taylor series for the sine, cosine, tangent and arctangent functions; the second-order Taylor series approximations of the sine and cosine functions and the third-order Taylor series approximation of the sine function; the power series of π, usually attributed to Leibniz but now known as the Mādhava-Leibniz series; the solution of transcendental equations by iteration and the approximation of transcendental numbers by continued fractions. Mādhava correctly computed the value of π to 9 decimal places and 13 decimal places, and produced sine and cosine tables to 9 decimal places of accuracy (see also Mādhava's sine table). He also extended some results found in earlier works, including those of Bhāskara.

$$\cos\theta = 1 - \frac{\theta^2}{2!} + \frac{\theta^4}{4!} - \frac{\theta^6}{6!} \dots, \qquad -\infty < x < \infty$$
$$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \frac{\theta^7}{7!} \dots, \quad -\infty < x < \infty$$

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[284] *Whish's paper, On the Hindu Quadrature of the circle, has been reproduced by T S Bhanumurthy in A modern introduction to Ancient Indian Mathematics, , Wiley Eastern, as an appendix.*

$$\frac{\pi}{4} = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \cdots, \qquad -\infty < x < \infty$$

Also Mādhava is known to have derived:
Sin (q+ h) = sin q + (h/r) cos q - (h/2r^2) sin q, and
Cos (q+h) = cos q - (h/r) sin q - (h/2r^2) cos q, which are special cases of the Taylor series (1700 AD)

39. VATASSERI PARAMEṢVARA NAMBOODRI CA.1380–1460

Parameṣvara Namboodri was possibly a direct disciple of Mādhava. According to a palm leaf manuscript of a Malayalam commentary on the Sūrya Siddhānta, Parameṣvara, a pupil of Saṇgamagrāma Mādhava, and a teacher of Nīlakaṇţa Somayājī was an Indian mathematician of the first rank and astronomer of the Kerala School of astronomy and mathematics founded by Mādhava of Saṇgamagrāma. Parameṣvara was a proponent of observational astronomy in medieval India and he himself had made a series of eclipse observations to verify the accuracy of the computational methods then in use. Based on his eclipse observations, Parameṣvara proposed several corrections to the astronomical parameters which had been in use since the times of *Āryabhaţa*. The computational scheme based on the revised set of parameters has come to be known as the *Drg Gaṇita* system. Parameṣvara was also a prolific writer on matters relating to astronomy. At least 25 manuscripts have been identified as being authored by Parameṣvara.[285]. The *Goladīpikā*—a detailed treatise dealing with globes and the armillary sphere was composed by Parameṡvara.
Bhatadipika - Commentary on Āryabhaţīya of Aryabhata I
Karmadipika - Commentary on *Mahabhaskariya* of Bhāskara I
Paramesvari - Commentary on *Laghubhāskariya* of Bhāskara I
Siddhäntadipikä - Commentary on Mahābhāskariyabhaṡya of Govindasvami
Vivarana - Commentary on Sūrya Siddhānta and Lilāvati
Drg Gaṇita - Description of the *Drk* system (composed in 1431 CE)
Goladipika - Spherical geometry and astronomy (composed in 1443 CE)
Grahanamandana - Computation of eclipses (Its epoch is 15 July 1411 CE.)
Grahanavyakhyadipika - On the rationale of the theory of eclipses
Vakyakarana - Methods for the derivation of several astronomical tables

40. DĀMODARA, SON OF PARAMEṢVARA FL.1430

Dāmodara was an astronomer-mathematician of the Kerala School of astronomy and mathematics who flourished during the fifteenth century CE. He was a son of Vatasseri Parameṣvara (1360–1425) who developed the drk Gaṇita system of astronomical computations. The family home of Parameṣvara was Vatasseri (sometimes called Vatasreni) in the village of Alattur, in Kerala. Damodara was a teacher of Nīlakaṇţa Somayājī. As a teacher he initiated Nīlakaṇţa into the science of astronomy and taught him the basic principles in mathematical computations. None of his original works seem to have survived.

41. NĪLAKAṆŢA SOMAYĀJĪ (1444 - 1545)

The most comprehensive work of the Kerala School available to us is the Tantrasańgraha of Nīlakaṇţa Somayājī along with commentaries on it by some of his followers. Fortunately the biographical details of Nīlakaṇţa are well recorded. He was born on Wednesday, June 14, 1444, and was a resident of Trkkantiyur (Sanskritized into Sri -Kundapura), near Tirur, Ponnai taluk, South Malabar. His teachers were Ravi with whom he studied

[285] *TOAII, PP.467 for a list of his publications*

Vedanta, and Damodara, son of Parameșvara, who initiated him into Astronomy and the underlying mathematical principles. That Nīlakaņţa lived up to a ripe old age, even to become a centenarian, is attested by a contemporary reference made to him in a Malayalam work on astrology Prasnasara composed in 1542-43. He earned his reverential appellation by mastering the Soma sacrifice. He belonged to the Gārgya Gotra and was a follower of the Āśvalāyana Sutra of the ṚgVedic tradition.

Nīlakaņţa's writings substantiate his knowledge of several branches of Indian philosophy and culture. In his writings he refers to a Mimamsa authority, quotes extensively from Pingala's chandas-sutra, scriptures, Dharmasastras, Bhagavata, and Vishnupuraṇa also. Sundararaja, a contemporary Tamil astronomer, refers to Nīlakaņţa as sad-darshani-parangata, one who had mastered the six systems of Indian philosophy[286]. Another major work of Nīlakaņţa is his Bhāsya on *Āryabhaţīya of* Āryabhaţa (476 CE). The lucid manner in which difficult concepts and cryptic astronomical calculations from Āryabhaţīya are explained, the wealth of quotations, and the results of personal investigation amply justify Nīlakaņţa referring to his work as a Mahābhāsya. Grahapareeksakrama is a manual on making observations in astronomy based on instruments of the time.

The Tantrasańgraha of Nīlakaņţa Somayājī along with commentaries on it by some of his followers has been critically edited by K. V. Sharma. Another source book, also by K. V. Sharma, is A History of the Kerala School of Hindu Astronomy; both these books have been published by the V.V.B. Institute of Sanskrit and Indological Studies, Punjab University, Hoshiarpur, Punjab.

42. JYEȘŢHADEVA (MALAYALAM) (*C. 1500 – C. 1610)*

Was an astronomer-mathematician of the Kerala School of astronomy and mathematics founded by Saņgamagrāma Mādhava (c.1350 – c.1425). He is best known as the author of *Yuktibhāṣā*, a commentary in Malayalam of Tantrasamgraha by Nīlakaņţa Somayājī (1444–1544). In Yuktibhāṣā, Jyeșthadeva had given complete proofs and rationale of the statements in Tantrasamgraha. This was noteworthy from many points of view, especially as it was written in Malayalam and not in Sanskrit. It was not unusual for traditional Indian mathematicians of the time to write an expository on what had already been written and the purpose of the Kārikas was to provide the gloss to the original works. A great majority of the Indic savants considered it their dharma to provide the pedagogy behind the original works, in order to make it more accessible to the lay public. It is this difference in outlook between the Occident and the ancient Indic that has caused much misunderstanding in the west regarding the place of proof in ancient India.

In the west there is an inordinate emphasis placed on original results and almost no PhD thesis escapes the key question 'What are the original results of your work'. The quest for originality takes on quixotic proportions and in the process there is less emphasis on developing sound insights into an existing paradigm.

An analysis of the mathematics content of Yuktibhāṣā has prompted some scholars to call it "the first textbook of calculus". Jyeşţhadeva also authored *Drk-karana* a treatise on astronomical observations.

43. SANKARA VARIYAR; STUDENT OF NĪLAKAŅŢA

SANKARA VARIYAR (circa. 1500 - 1560 CE) was an astronomer-mathematician of the Kerala School of astronomy and mathematics who lived during the sixteenth century CE. His family members were employed as temple-assistants in the Shiva-temple at Trkkutaveli near modern Ottapalam. Sankara Variyar sis especially interesting in that he may very well have been the Indian Pandit who transmitted the knowledge to the Jesuits who arrived in large numbers to learn the intricacies of the Indian calendar and the Indian techniques of navigation.

[286] *Sundararaja , Contemporary Tamil systems of Indian philosophy*

Mathematical lineage: He was taught mainly by Nīlakaṇṭa Somayājī (1444-544), the author of the celebrated Tantrasamgraha and Jyesthadeva (1500 – 1575), the author of Yuktibhāṣā. Other teachers of Sankara Variyar include Netranārāyana, the patron of Nīlakaṇṭa Somayājī and Chitrabhanu, the author of an astronomical treatise dated to 1530 and of a small work with solutions and proofs for algebraic equations.
Works of Sankara Variyar. The known works of Sankara Variyar are the following:
Yukti-dīpīka - an extensive commentary in verse on Tantrasamgraha based on Yuktibhāṣā.
Laghu-vivrti - a short commentary in prose on Tantrasańgraha.
Kriya-kramakari - a lengthy prose commentary on Līlāvati of Bhāskara II.
An astronomical commentary dated 1529 CE.
An astronomical handbook completed around 1554 CE.

44. ACHYUTA PISĀRATTI, 1550–JULY 7, 1621 CE OF TRIKKANTIYUR,

Acyuta was the disciple of Jyeṣṭhadeva. In Sphutanirnaya (Determination of True Planets) he details an elliptical correction to existing notions. Sphutanirnaya was later expanded to Rāśigolasphutānīti (True Longitude Computation of the Sphere of the Zodiac).
Karanottama deals with eclipses, complementary relationship between the Sun and the Moon, and 'the derivation of the mean and true planets'. In Uparāgakriyākrama (Method of Computing Eclipses), Acyuta Pisārati suggests improvements in methods of **calculation of eclipses.**

45. PUTUMANA SOMAYĀJĪ (C. 1660-1740)

Belonged to the Kerala School. Wrote Karana Paddhati (early 18th century) a compendium of results available till that date. A brief account of the contents of the various chapters of the book Karana Paddhati is presented below.

Chapter 1: Rotation and revolutions of the planets in one Mahāyuga; the number of civil days in a mahāyuga; the solar months, lunar months, intercalary months; kalpa and the four yugas and their durations, the details of kaliyuga, calculation of the Kali era from the Malayalam Era, calculation of Kali days; the true and mean position of planets; simple methods for numerical calculations; computation of the true and mean positions of planets; the details of the orbits of planets; constants to be used for the calculation of various parameters of the different planets.
Chapter 2: Parameters connected with Kali era, the positions of the planets, their angular motions, various parameters connected with Moon.
Chapter 3: Mean center of Moon and various parameters of Moon based on the latitude and longitude of the same, the constants connected with Moon.
Chapter 4: Perigee and apogee of the Mars, corrections to be given at different occasions for the Mars, constants for Mars, Mercury, Jupiter, Venus, Saturn in the respective order, the perigee and apogee of all these planets, their conjunction, their conjunctions possibilities.
Chapter 5: Division of the kalpa based on the revolution of the planets, the number of revolutions during the course of this kalpa, the number of civil and solar days of earth since the beginning of this kalpa, the number and other details of the Manvantaras for this kalpa, further details on the four yugas.
Chapter 6: Calculation of the circumference of a circle using variety of methods; the division of the circumference and diameters; calculation of various parameters of a circle and their relations; a circle, the arc, the chord, the arrow, the angles, their relations among a variety of parameters; methods to memorize all these factors using the katapayadi system.
Chapter 7: Epicycles of the Moon and the Sun, the apogee and perigee of the planets; sign calculation based on the zodiacal sign in which the planets are present; the chord connected with rising, setting, the apogee and

the perigee; the method for determining the end-time of a month; the chords of the epicycles and apogee for all the planets, their hypotenuse.

Chapter 8: Methods for the determination of the latitude and longitude for various places on the earth; the R-sine and R-cosine of the latitude and longitude, their arc, chord and variety of constants.

Chapter 9: Details of the α Aries sign; calculation of the positions of the planets in correct angular values;; calculation of the position of the stars, the parallax connected with latitude and longitude for various planets, Sun, Moon and others stars.

Chapter 10: Shadows of the planets and calculation of various parameters connected with the shadows; calculation of the precision of the planetary positions.

FIGURE 13 JAISINGHS SAMRAT YANTRA, THE WORLDS LARGEST SUNDIAL (JAIPUR)

PROMINENT MEMBERS OF DAIVAJNA FAMILY

- **NĀRĀYANA (FL.1351-1388) SON OF NṚṢIMHA DAIVAJNA(1) (FL.1300 CE)**
- **GANESA DAIVAJNA (1507 CE) SON OF LAKSHMI AND KESAVA**
- **MALLARI FL. 1575 -1600**
- **NṚSIMHA (2) B. 1586**
- **KAMALAKARA DAIVAJNA (1616)**



We speak of the Kerala astronomers as if they were the sole unique example of a regional parampara with substantial advances to their credit. While the Kerala School undoubtedly produced many original thinkers, the rest of the country was definitely not idle. The reality is that there was a continuous stream of astronomers till the advent of the 20th centuries. As we have already mentioned there are the Daivajna of the Asmāka country in the upper Godavari river valley (currently in Mahārashtra). Although I daresay it was no longer referred to as such by the time of the fifteenth century. The Asmāka country features as the place where AB and Bhāskara I hailed from. The significance of the Asmāka country is that it was where the capital of the Southern branch of the Sātavāhana was located in Paithan (Pratishtan). Incidentally it happens to be in the same longitude as Ujjain and Delhi. Furthermore the Sarasvati Sindhu civilization, contrary to the inference that it was restricted to the Indus and the Sarasvati river Valleys, extended to the Godavari river valley and there is reason to believe that Pratishtan was a major center of that civilization. The location had many advantages and it is not a surprise that it would prove to be the place with the longest period of continuous urban settlement in the Indian subcontinent. There is one other point to be made here, even if we have made it elsewhere and that is even amongst those astronomers that we would consider among the short list of the most brilliant astronomers, there never was a reluctance to write a commentary on the work of their predecessors. So it is not surprising that there are over 15 commentaries on the Āryabhaṭīya. This is to be contrasted with the prevailing convention in the west where it is rare to see the first rank scientist writing a commentary on the work of another first rank scientist. This shows the great importance that the Indics placed on correct understanding of existing knowledge before propounding new theses.

Most of the Daivajna mentioned in this list hail from the Asmāka region.

Nārāyana (FL.1351-1388) composed his works during the time of Firoz Shah Tughlak. He composed two works, the Gaṇitakaumudi (1556 CE) on arithmetic and one on Algebra, Bījaganitavataṃśa.

Ganesa (1507) wrote Buddhivilasini a commentary on Līlāvati and Grahalāghava one of the famous karana texts used even today.

47. KAMALAKARA DAIVAJNA

Who flourished during the reign of Aurangzeb was the son of Nṛṣimha Daivajna and he hails from a long line of Daivajnas. ***Siddhāntatattvaviveka*** *was composed* by Kamâlakara (seventeenth century CE) (1935) Sudhakar Dwivedi.

46. MUNISWARA VISVARUPA

Muniswara Born 17 March 1603. Muniswara was a member of a Varanasi parampara of Astronomers who were contemporaneous with Kamalakara. Authored the Siddhantha Sarva Bhauma (completed 8 Bhādrapadā, Ṡaka 1568 or 7 September 1646. He was the main astronomer in the court of Shah Jahan, the 5th among the 6 well known Mughal emperors. He wrote a commentary on Līlāvati and another text on mathematics called the Patisara.

47. JAISIMHA (JAISINGH II) 1686-1743

Led Amber of Rajasthan under the nominal suzerainty of the Mughal Emperor. However, the Mughal was severely compromised as the supreme authority in North India by this time. While he directed the production of Zij Muhammad Shahi, and wrote a few works himself he will be remembered more for his vast knowledge and vision in building a series of observatories in North India. He studied Hindu, Islamic, and Ptolemaic theories as well as being familiar with the work of the observatories of Al Tūsi, Ulugh Beg and Tycho Brahe He found time to do all of this besides meeting the strategic needs of maintaining a fairly large empire even though his personal rule did not extend over a large territory (Amber). He was instrumental in directing the building of several observatories using the basic architecture of the Samrat Yantra to collect data.

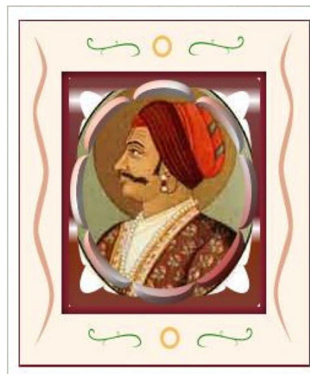


FIGURE 12
JAISIMHA MAHARAJA JAISINGH

48. JAGANATH PANDIT (FL. 1700)

Jaganath Pandit (fl. 1700) was the astronomer attached to the court of Mahāraja Jai Singh (the builder of the Jantar Mantars). It is astonishing that the first translation of Euclid into Sanskrit was done By Jaganatha in the late 18th or early 19th Century. It is alleged by the cognoscenti of the Occident that the ancient Indics plagiarized from the Greeks especially in Geometry. I fault the Indics for precisely the opposite reason that it took them 2200 years to translate Euclid into Sanskrit For a people so lackadaisical and totally lacking in curiosity about what others may have learnt, it does not seem in character that they would have traveled to Babylon or Alexandria just to learn what the Babylonians or the Greeks knew of Geometry.

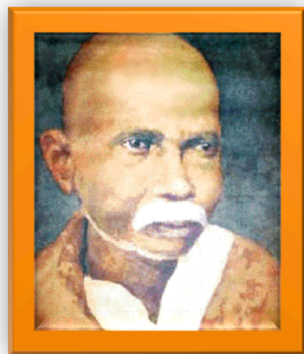
49. GHULAM HUSSAIN JAUNPURI (FL.1838)

Compiled the Zij –I Bahādur Khāni. It is based on the Zij I Mohammad Shāhī initiated by Jaisimha

50. CHANDRA ṠEKHARA SĀMANTA (1836 – 1904)

By now we have established the proposition that the tradition of Astronomy as it developed in India, in its own unique way provided a continuous source of Astronomers during almost all the entire period from Dīrghatamas in the 4th millennium BCE and Āpastamba to Sāmanta Chandra Śekhara in the nineteenth century. But who is Sāmanta Chandra Śekhara and how many of us know his contributions. Even at such a late stage in the nineteenth century he was able to improve upon the existing knowledge by identifying the errors accumulated over the ages, in the parameter used for the computation of longitudes. The fact that he did not have access to an observatory did not seem to deter him even one iota and all his work was carried out using naked eye observations.

FIGURE 14
CHANDRA ŚEKHARA SĀMANTA



Sāmanta Chandraśekhara was born into the royal family of the estate of Khandapara in Orissa in Dec 13, 1835, Pusya Astami of Śalivahana Saka year 1757. It is a small village, about 60 miles to the West of Bhuvaneshwar, surrounded by hills and jungles. By the age of fifteen he was able to compare his own observations with those in the Sūrya Siddhānta. He was surprised to find that his observations did not agree with those in the Siddhanta Siromani and the Sūrya Siddhānta.

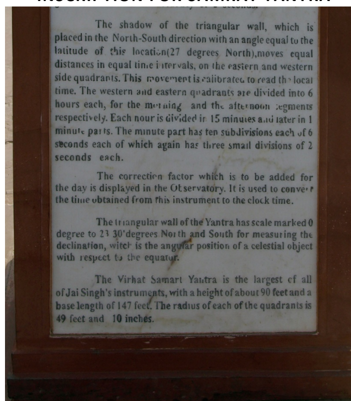
Alternate Birthdate Nov 1, 1836 (Tuesday), Pausa Krishna paksha, 7/8 1892 Vikramabda, 1757 Śaka, Lat 20° 15′, Longitude 85° 6′.

SOME BROAD REMARKS ON INDIC SAVANTS

It is my contention that the ancient Indic was not driven by the compulsion to produce original results so much as to solidify the insights that his predecessors had bequeathed to him. This would explain why in spite of severe lack of academic institutions India continued to produce world class astronomers till the time of Chandraśekhara Sāmanta in the Nineteenth century. It is not surprising that a century later, by which time the ancient tradition was fast disappearing, Astrophysicist Chandrasekhar felt a high degree of responsibility to fulfill his pedagogical responsibilities. To illustrate this characteristic, it would not be out of place to recount an incident in the Nobel Laureate's life. In the 1940s, while he was based at the University's Yerkes Observatory in Williams Bay, Wis., he drove more than 100 miles round-trip each week to teach a class of just two registered students at Chicago. Any concern about the cost effectiveness of such a commitment was erased in 1957, when the entire class–T.D. Lee and C.N. Yang–won the Nobel Prize in physics. In fact they won it at a time when Chandraskhar had not won the Nobel yet. There are three papers on Brownian motion in Nelson Wax's[287] "Selected papers in Noise and Stochastic Processes." Chandrasekhar's expository paper is one of them. I will let the reader decide which one ranks high in pedagogy.



FIGURE 15 EXPLANATORY STONE INSCRIPTION FOR SAMRAT YANTRA



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[287] *Nelson Wax Selected Papers on Noise and Stochastic processes, Dover, NY.*

QUOTE

"There is always happiness, wealth, and prosperity to those around whose neck, a chaste and pure lady called ***Līlāvati,*** *belonging to a respectable family, endowed with good virtue, throws her arms.*
This is how Bhāskara II ends his text called Līlāvati. Bhāskara II uses double entendre's to make the subject of Līlāvati more palatable. We cite one more example of Bhāskara's use of imagery to make the subject more interesting, "During an especially energetic amorous session, a necklace around the neck of the eager lady broke and caused the row of pearls to be separated. One third fell to the floor. One fifth stayed upon the bed. The young woman saved one sixth of them. Her lover caught One tenth. If six pearls remained upon the string, how many pearls were there altogether in the necklace originally?

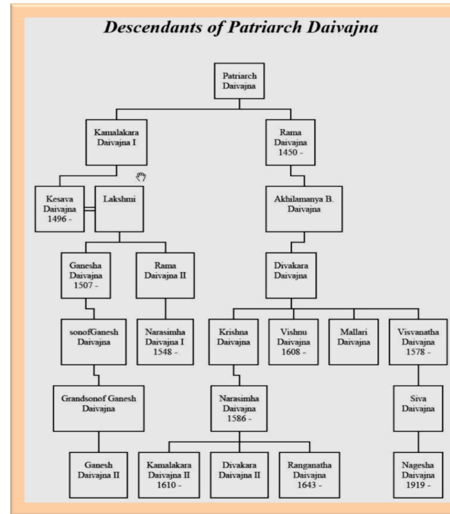


FIGURE 11 ASTRONOMERS WITH THE PATRONYMIC OF DAIVAJNA (A LARGE NUMBER WERE FROM THE MAHĀRASHTRA REGION AND BELONGED TO THE KAUSIKA GOTRA

CHAPTER XII EPILOGUE
PARADIGM SHIFT FROM A KINEMATIC MODEL TO A PHYSICS MODEL

A word is therefore in order about the manner in which we construct the models of the universe. It is only in the last 500 years, or even less, that we have shifted unambiguously to a heliocentric view of our Solar system. This step was a major paradigm shift for the human species. But this does not mean that the geocentric models that were constructed in the past were wrong or that the models were an obstacle to further progress. Nor does it mean that the ideas leading inexorably to a heliocentric model, such as the realization that the earth rotates about its own axis , did not occur to those who were capable enough to visualize the consequences (Āryabhaṭa and Aristarchus come to mind). It simply means that the species had not evolved to the point where it could appreciate the consequences of the heliocentric model.

From time immemorial, humans have been watching the periodical rising and setting of the objects in the sky including the Sun, the Moon, and the planets. One cannot help but ask the question, why is this happening', and how did they collect the data and when did they come up with the computational algorithms that were needed to determine the positions (latitude, longitude) of the various heavenly bodies. There are more questions rather than real answers. However, the ancients made several observations that can be forensically examined in order to arrive at the truth.

NO ROMAN EVER LOST HIS LIFE IN THE CONTEMPLATION OF A MATHEMATICAL DIAGRAM

'No Roman ever lost his life because he was absorbed in the contemplation of a mathematical diagram.' remarked Alfred North Whitehead, the well-known British Mathematician, while commenting on the legend of the death of Archimedes at the hands of a Roman soldier. But what of the Ancient Indic? What if anything, would he have wished on his epitaph?

Despite his pragmatism, the Indic of antiquity would probably wish to be remembered for his love of knowledge for its own sake and for his insatiable quest to quantify the universe around him. I do not believe any of the Ancient Indics lost much sleep over the fact that they would be accused of borrowing everything from the Greeks. Au contraire, they would have been amused at the inordinate amount of time spent by otherwise intelligent individuals to prove that they – the ancient Indic - plagiarized everything from the Greeks and that they were not of such great antiquity. After all can there be a greater compliment to a person than to study his works for the greater part of one's life, even after the lapse of 2 or more thousand years.

We have covered a great distance in this book. My purpose in writing this book was primarily to tell the story of Ancient Indian Astronomy to an audience that includes those who are not of Indic ancestry. We have tried to tell the story in the manner in which it should be told. While we do not try to hide our belief that the story of Ancient Indian Astronomy is one of great antiquity, we feel we have adhered to the truth scrupulously as we know it today and have not made any claims for which we do not have an

adequate data or evidence. At no time in the narrative have I suggested that the Ancient Indic was the sole source of knowledge in the computational sciences. The evidence suggests however that the Indic was the first to progress to computational astronomy with algebraic and trigonometric expressions. We have maintained that his contributions were unique and original and some of these unique approaches became part of the mainstream. Even this is rarely acknowledged in public.

There are certain omissions we had to make, as we could not cover the subject in an encyclopedic manner. Having said that, there is a lot of material here to fill many lectures. We could not go into the details of the calculation to determine longitude and latitude of the planets as we ran out of pages. We have not touched upon the instrumentation aspects, which while being pre-Galilean is a very interesting story. Some of these topics await the 2nd volume of this book. We did not include autobiographical sketches on all 200 of the Indic savants. Our treatment of Jaina astronomy is cursory at best. Our treatment of Ancient Indian Mathematics is restricted to topics that arise in the context of Calendrical Astronomy. I have tried not to get into advanced areas and have attempted to maintain the technical content of the material at an introductory level so that those who may not have an advanced math Background will appreciate the logic behind some of the inferences.

Even with all of these omissions we feel we have managed to cover a lot of topics necessary to make the reader a highly competent naked eye astronomer, capable of understanding of the main issues involved in Observational & Calendrical astronomy. In addition there is an extra bonus, in that the reader will for the first time have at his fingertips all the necessary data and resources to undertake the study of comparative astronomy of various civilizations should he so choose.

The real value of the book is to bring the reader up to date on a broad range of topics and issues relevant to the origins of calendrical astronomy. We have tried to impart the notion that Astronomy was more than just a playground for the Europeans.

In the process we have established a prima facie case that our Heritage in Astronomy was not just a legacy of the Greeks but of all of humankind and to reach where we are today we stand on the shoulders of giants who hailed from various parts of the globe and not just Greece or Babylon. We have put forward a chronology that is consistent both internally and externally and does not violate the known facts about Indic History. We have made a convincing case that Hindu or Ancient Indic Astronomy Is of great antiquity and the ancient Indic was using reasonably accurate calendars a very long time ago (terminus ante quem of 4000 BCE).

ANCIENT INDIC MATHEMATICAL ASTRONOMY HAD A UNIQUE CHARACTER.

The use of epicycles as well as eccentric circles were known to the Indics before the Greeks and are mentioned in the Sūrya Siddhānta, a text that is considered by informed Indic historians to be a literary document contemporaneous with the era prior to the common era.

We have given reasons why we believe that David Pingree (as well as his Guru Otto Neugebauer) was grossly in error when he made the oft-repeated assertion that India borrowed much from Greece. Obviously one must exercise due diligence and study the vast Indic literature before making such a priori

judgments, judgments that David Pingree has been making since his introduction to the subject during the period when he wrote his PhD thesis on Greek transmission of Astronomy to India.

We feel he is wrong both from a chronological standpoint as well as from epistemological standpoint. There is epistemological continuity in the approaches that the Indics used going back several millennia till the advent of the Colonial era. It is only after the mandatory imposition of English that such an epistemological continuity was broken. Currently the Indic is in the process of synthesizing the ancient episteme with the Occidental systems of knowledge that he has imbibed along with the English language and once he reaches equilibrium in this transition there is no reason why he may not continue to advance the state of the art as he once did.

While we have compared the Indic achievements to those in Greece, this was not to suggest that the Greeks contribution was insignificant, especially in the axiomatic approach to mathematics. The fact remains that the only extant documentation on Greek astronomy dates to a time that is significantly later than the Golden age of Greece. We take issue mainly with the current day Historians of Mathematics in the Occident whose main interest appears to be in claiming priority of invention in a retrospective manner in every field of human endeavor, and their unwillingness to concede priority to the ancient Indic even in those cases where there is no documentary evidence of the Greek effort. Trigonometry is a case in point. Their views are so full of clichés, that the final result is almost fatally flawed and banal to the point where it competes strenuously with the superficial views of India which I lump under the lumpen category of the 'Cows, Caste and Curry' characterization of India, that is peddled as being representative of India. Unfortunately such superficial assessments abound among even the top rungs of journalists and public leaders in the occident. When such assumptions color their judgment, it is impossible to take the rest of the work seriously.

We have devoted an entire chapter to Astronomical dating, since we feel that the precession of the equinoxes provides a very reliable clock with a period of approximately 25,800 years. Such a large period is particularly fortuitous since this is in the same order of magnitude as the entire length of recorded history that spans about 10 millennia. We have run planetarium software for the entire matrix of 27*4 = 108 equinoctial/Solstitial events for one complete precessional cycle that can be used as a reference, when the reader comes across such an event or observation to determine the date of the event. These calculations simulate the effects of the drift of the aphelion that takes about 120,000 years to complete one cycle. It is a simple matter to interpolate the dates of other events such as the equidistant locations on the sidereal zodiac (13.33, 26.67, 40 …etc.).

While transmission of ideas and knowledge is a continuous process, we believe that there have been 4 periods in recorded history that can be characterized as periods of more than average transmission activity.

1. The first wave of transmission during which there appears to have been a period where migration took place after the Dasarajna War (mentioned in the Ṛg Veda) where there was migration of Druhyus and other clans. The Kassites appear mysteriously in Babylon worshipping Hindu deities. The Ionians could very well be the culmination of the resulting Yavana migration.

2. The second transmission took place indirectly via Iran from Jundishapur, where Indic astronomy was well known when Alexander looted ancient Persia and had the loot of books shipped to Alexandria.
3. The third period of intense transmission occurred when an individual named Ganaka or Kanaka, presented himself to the Khalif al Mansur in Baghdad as an expert in computational astronomy. I include Al-Khwarismi's work in this category.
4. The transmission that took place from 1500 onwards is the one that is most hidden from scrutiny, despite the fact that it is the most recent one, but we have cited at least 4 instances in the book of such a transmission and there are undoubtedly many more.

We have catalogued several instances where the Occidental has either ignored the Indic contribution or consciously belittled it. We have given the example of George Thibaut and George Kantor ignoring the prior antiquity of the Sulva Sutra despite the fact that they were aware of the Sulva Sutras and had in fact created an English version of the same. We have used the word Occidental on several occasions in this book. We feel that such a gross generalization of people living in such a vast area is nevertheless very appropriate, since it is by choice that the Western savant has chosen to be largely monolithic in his views on India, especially when it comes to topics that indicate a high degree of antiquity.

THE LEGACY OF THE ANCIENT HINDU

In fact after I wrote the Origins, I was more than ever convinced that the revolution that ensued owed more than ever to the many astronomers that graced the Indian subcontinent, and should properly be termed the ĀRYABHAṬA - NĪLAKAṆṬA - SĀMANTA evolution , in honor of all the Indian astronomers who painstakingly ferreted out the secrets of the solar system. We have already mentioned the names of ĀRYABHAṬA AND NĪLAKAṆṬA SOMAYĀJI, but who is Sāmanta you might ask. He is the Last of the Mohicans[288], the Chingachgook of Indian astronomers, the traditional naked eye astronomers imbued with a very modern mind. There is not sufficient space to go into his vast contributions here of which we give a glimpse in the Origins, but we encourage the reader to investigate as a starter, two books[289]. I am confident that after studying the Siddhāntic models, with its greater understanding of relative motions between the interior planets, earth and the outer planets, culminating in the Nilakanta Tycho model, most historians would realize that the Indian effort was the more logical stepping stone to the Kepler Newtonian formulation, and the Ptolemaic model with its heavy reliance on the compass and straight edge, the circular orbit dogma and its primitive trigonometry was in fact a hindrance to proceed to a physics model.

Again as in the case of Analysis and the Calculus, we agree with Richard Courant that it make little sense to say that one individual was responsible for the evolution to a model where the physics was the key, but we can say that certain individuals like Sir Isaac Newton, the Great Swiss family of Bernoulli's, Leonhard Euler, who regarded himself as belonging to the Bernoulli parampara and the wonderful

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[288] *James Fennimore Cooper 'the Last of the Mohicans', is a piece of historical fiction by an American author set in 1757 during the peak of the Anglo French Rivalry Chingachgook is portrayed as a Noble and highly principled warrior chief of the Mohawk, part of the 6 nation confederacy that allied with the British against the Huron who allied with the French.*

289 *Siddhanta Darpana, Eng. tr. by Arun Kumar Upadhyaya, Nag Publishers and Ancient Indian Astronomy and Contributions of Sāmanta Chandra Sekhar by L. Satpathy (ed.). Narosa Publishing House, New Delhi. 2003.*

work done by the bevy of French mathematical astronomers (Joseph Louis Lagrange, Jean le Rond D'Alambert, Pierre Simon de Laplace, Augustine Cauchy , Simeon Dennis Poisson) made major contributions to the new science of Mechanics. And so our story of the origins of Astronomy ends here at the point where Mechanics matures into a subject of study in its own right. This is where I had begun my quest into the understanding of our universe four decades ago.

Much water has flown through the Ganges, the Seine, the Elbe, the St. Lawrence and the Mississippi, during those decades but my love of Mechanics and Mathematics has never waned and my desire to see that proper recognition be given to those practitioners in the past who were brushed aside has kept me focused on telling this story, especially when nobody else came forward to do so.

In the end, the Indics lost the battle for supremacy in the Sciences to the Europeans in the Seventeenth century of the common era but at the same time the Indic can take comfort in the fact that the ancient Indic has left behind a huge cornucopia of treasures and a legacy of thinking rationally about problems and habits of thought that will endure long after the Pyramids decay into dust. He has taught us how to count, how to convert an angular measure into a linear one, how to use analysis in the service of mankind, how to systematically solve a problem so that each step could be executed precisely as he would have wanted it implemented even after the lapse of a thousand years the forerunner of a computer code that is readily interpreted. He taught us that Etymology should be part and parcel of a dictionary. He taught us the science of semantics. And he reduced the study of language to a set of grammatical rules, so that we need not place the words in any particular order. Most importantly he cautioned us not to get too cocky with our mathematical models and assume they were divinely inspired in contradistinction to the Greeks and their successors, and by implication that we should be ready to discard our models once their usefulness had worn of.

In this connection. It is relevant to recall the remarks that the preeminent French historian of science Pierre Duhem makes with respect to mathematical models. Duhem classifies models into 2 categories one in which the models can be regarded as convenient fictions devised by mathematicians to aid in making calculations, and the second which aims to describe the fundamental nature of the physical laws needed to describe the motions of celestial bodies. To get into the distinction between these two categories is an interesting exercise, but the point I wished to make is that the Indic did not negate the possibility of there being ontological principles that need to be enunciated simply because he has a mathematical model that works. In that respect he was already showing sufficient sophistication in recognizing the distinction between a solution satisfying one or more necessary conditions to one which has to satisfy both necessary and sufficient conditions.

CONCLUSIONS

In those instances where the evidence was overwhelming that the Indics were responsible for a paradigm shift, leading to a greater capability such as for instance the impact of the decimal place value system on mathematical astronomy, the Occidental has for the most part, refused to acknowledge that the Indics had an advantage. He refuses to acknowledge that Europe was lagging behind in several fields including Mathematics and that it is only during the start of the colonial era that Europe decisively shot ahead.

The epistemic heritage of a civilization plays a key role in the history of the people. There are many questions to answer. What role does knowledge (Gyāna) play in the ethos of the civilization? Does the civilization value knowledge for its own sake or does the knowledge need to have a utility in order for us to be motivated to pursue it? We have tried to belabor the point that the ancient Indic has been responsible for bequeathing to India a unique epistemic heritage, the core values of which were universally appreciated. We have also made the point that the current perception of mediocrity of this civilization is only of recent vintage. There can be little doubt that the body politic of India is undergoing a massive epistemic rupture as we speak, a rupture that began when the colonial Overlord decided consciously to devalue the heritage of the Indian people. Before the Indian decides that there is very little to preserve from the past, he or she should inform himself of the true facts regarding the past. He should internalize the value of epistemic continuity in a civilization by studying the correlation between successful civilizations and the epistemic continuity in their history. Only then can he make an informed choice.

'India does not have a history' is the popular refrain amongst Indologists west of the Bosphorus. In reality Indian calendars were far more accurate for most of recorded history and Indian records were superior compared to anything that Greece had in 2000 BCE or even as late as the Roman era. For example the Greeks did not have an Ahargaṇa system and had to do considerable guessing when there were gaps in the record. They reckoned their calendars in terms of the regnal period of the Archon of Athens. In fact it was only after the Julian day count was instituted by Justus Scaliger in 1582, was it possible to get an accurate day count from a day in the distant past. This explains why it is almost impossible to quote an accurate date of birth in the Occident, till a couple of centuries ago, unless you belonged to the Nobility or the Royalty. We trust that future generations of Indologists will not make such an asinine claim anymore.

We have established beyond a shadow of a doubt that the occidental claim to priority of Greek Science and Astronomy has absolutely no basis in fact and is accompanied by statements such as those of Pingree, that we quoted earlier "*History shows that essentially all of the methods and many of the parameters of Indian astronomy, prior and subsequent to the fifth century CE, were derived from Mesopotamia and Greece; it also is apparent that the planetary models of the Brahmagupta, Ārya Pakṣa, and Ardharātrika Pakṣa are of Greek origin*. So categorical is the assertion that most Indics faced with such certitude would tend not to question such emphaticity. This would be a major tactical error. If I may be permitted to paraphrase Bertrand Russell's[290] admonition; *the method of simply assuming results, once one is persuaded that they are true, rather than trying to prove them,* (*as in the case of Greek priority over the Indics), has all the (accoutrements and)advantages of thievery over honest toil.*

We are confident that the reader who approaches this book with an open mind will be convinced that the book provides a fresh but what we believe to be an accurate perspective on the History of the Computational Sciences in Ancient India and its pioneering spirit in the ancient era.

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[290] Russell Bertrand, Introduction to Mathematical Philosophy, New York and London, 1919, p.71

APPENDICES

APPENDIX A GLO-PEDIA

A

Abda - Year (as in Yugabda 5110 (2009)

Aberration- An effect caused by the Earth's motion that slightly changes the positions of stars. James Bradley discovered aberration of starlight in 1728. This was the first direct proof of the Earth's movement around the Sun.

Abhaya*:* The gesture of protection. In this hand-pose, the palm of the hand is fully open and the fingers point upwards. The palm faces the onlooker.

Abhijit, *अभिजित* Abhijit Nakṣatra: Abhijit Nakṣatra is called the intercalary(IC) Nakṣatra as it appears as a small (smaller duration as compared to normal duration of Nakṣatra $13^{o}20^{'}$)[291] Nakṣatra between Uttara Āṣāḍhā and Srāvana. The duration of Uttara Āṣāḍhā is divided into four parts and the first three pādas are assigned to Uttara Āṣāḍhā, which makes the duration of Uttara Āṣāḍhā to be 10^{o} with each pādā to be 2d 30m. The remaining one pādā of Uttara Āṣāḍhā is assigned to Abhijit, the intercalary Nakṣatra. Similarly beginning 1/15th part of Srāvana is given to Abhijit, making its total length to be $253^{m}.33$, i.e., $4^{h}\ 13^{m}\ 20^{s}$. The remaining 14/15th part of Śrāvaṇa is assigned to the four pādās of Śrāvaṇa, making the total duration of Śrāvaṇa to be $12^{d}\ 26^{m}\ 40^{s}$.

Acyuta Pisārati, 1550–July 7, 1621 CE *of Trikkantiyur, was the disciple of Jyeșţhadeva,*

In, Sphutanirnaya (Determination of True Planets) details an elliptical correction to existing notions. *Sphutanirnaya* was later expanded to *Rāśigolasphutānīti* (True Longitude Computation of the Sphere of the Zodiac).

Karanottama deals with eclipses, complementary relationship between the Sun and the Moon, and 'the derivation of the mean and true planets'. In *Uparāgakriyākrama* (Method of Computing Eclipses), Acyuta Pisārati suggests improvements in methods of **calculation of eclipses.**

Adharma, अधर्म absence of righteousness, disorder, evil, immorality

Adhimāsa, Adhikamāsa, **अधिकमास** or intercalary **month** - Leap month or intercalary month introduced to account for the lack of synchronization between a Lunar period and a Solar period, i.e., the Solar period (or year) is not an exact multiple of a Lunar month. Literally means additional month. An intercalation takes place when 2 Lunar months begin in the same Solar month; the former of the 2 is called the intercalary month or adhikamāsa. Thus intercalary months in a Yuga = Lunar months in a Yuga – Solar months in a Yuga.

Adhiyajna: altar

Adhyāsa, अध्यास- used to refer to the 'mistake' that we make when we 'superimpose' a false appearance upon the reality or mix up the real and the unreal.

Adhva, distance of place from meridian

Adrishta, opposite of drishta or Unseen, a metaphor for the consequences of past actions, which may be unanticipated

Advaita, not two (Dvaita)

Aeon, has more than one meaning**,** a very large period of history, a divine power or nature emanating

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[291] *Note the distinction between arc minutes (') and minutes of time. One is an angular measure and the other is a measure of time, but there is equivalence, stemming from the diurnal rotation of the earth. Since 24^{h} is equivalent to 360^{o}, 1^{h} is equivalent to 15^{o} of arc length, i.e. it takes 1^{m} of time to traverse 15' (arc minutes)of angular measure. This applies both to longitudes as well as Right Ascensions.*

from the Supreme Being and playing various roles in the operation of the uiverse. Read more: http://www.answers.com/topic/aeon-1#ixzz1G22rzwbLn

Ahargana अहर्गण the **NUMBER** of days elapsed from a reference epoch. (See also Julian day number.) The common practice in ancient Greece was to reckon each period from the accession of Archon of Athens. Such a system is prone to errors and Greek history for all the vaunted prowess of the Greek in Astronomy is so uneven in its accuracy that we do not to this day know the date of Euclid and whether in fact there was an individual named Euclid. The situation with Ptolemy is not much better, virtually nothing is known about the most famous Astronomer in Alexandria including the date of his birth. The computational prowess of the Indics and the rapidity with which they established themselves as the masters of the algorithm, made them comfortable with the use of large numbers. By developing a rapport for the manipulation of large numbers the Vedic scholar of yore made a virtue out of necessity, but he was never carried away by Numerology nor did he ever make a fetish of it like the followers of Pythagoras.

Ahaṁkāra ego

Ahavanīya fire: The Vedic Fire Altar has three *fire-altars.* Of these, the one on the east-west line on the eastern side is the Ahavanīya Fire and is square in shape. It denotes the heaven-world. All other Fires are lighted from this celestial fire.

Ahimsa*, अहिम्सा*-abstention from injury to all life forms

Ahorātra a complete 24 hour day (the Greek word for this is **nychthemeron**)

Airavata: The name of Indra's elephant. He is the vehicle of Indra, the king of the Gods.

Akṣa Latitude, the term Akṣa is a abbreviation of the complete term Aksakonnati, meaning the inclination of the Earth's axis (to the plane of the celestial horizon), i.e. the terrestrial latitude of the place**, Akṣāmṡa**, अक्षाम्श

Aja ("goat"): sun, Capricorn (?)

Akṣachapa arc of latitude

Akṣa Jiva, AksaJya the R sine of the latitude

Akṣa karna equinoctial midday shadow

Akṣakonnati inclination of the earth's axis: obliquity

Akṣakoti co latitude

Akṣamala*:* Rosary of beads, which is of two types, **(i)** Rudraksha, and **(2)** Kamalaksha. The rosary is usually found in the hands of Brahma, Sarasvati, and Siva. Sometimes it is found with other divinities also.

Alfonsine Tables see Figure 22 in Chapter 1

Algorism, Algorismus, Algorithm Algorism is the technique of performing basic arithmetic by writing numbers in place value form and applying a set of memorized rules and facts to the digits. One who practices algorism is known as an algorist. This system largely superseded earlier calculation systems that used a different set of symbols for each **n**umerical magnitude and in some cases required a device such as an abacus**.** The word *"Algorism"*, comes from the name Al-Khwārizmi (c.780-850), a Persian mathematician, astronomer, a geographer and a scholar in the House of Wisdom in Baghdad, whose name means *"the native of* Khwarezm*"*, a city that was part of the Greater Iran during his era and now is in modern day Uzbekistan He wrote a treatise in Arabic language in the 9th century, which was translated into Latin in the 12th century under the title *Algoritmi de numero Indorum*. This title means "Algoritmi on the numbers of the Indians", where "Algoritmi" was the translator's Latinization of Al-Khwarizmi's name. Al-Khwarizmi was the most widely read mathematician in Europe in the late Middle Ages, primarily through his other book, the Algebra. In late Medieval Latin, *algorismus*, the corruption of his name, simply meant the "decimal number system" that is still the meaning of modern English **algorism**. In 17th century French the word's form, but not its meaning, changed to *algorithm*, following the model of the word *logarithm*, this form alluding to the ancient Greek *arithmos* =

arithmetic. English adopted the French very soon afterwards, but it wasn't until the late 19th century that "Algorithm" took on the meaning that it has in modern English. In English, it was first used about 1230 and then by Chaucer in 1391. Another early use of the word is from 1240, in a manual titled *Carmen de Algorismo* composed by Alexandre de Villedieu. It begins thus:

"Haec algorismus ars praesens dicitur, in qua Talibus Indorum fruimar bis quinque figuris."

"Algorism is the art by which at present we use those Indian figures, which number two times five."

The word Algorithm also derives from *"Algorism"*, a generalization of the meaning to any set of rules specifying a computational procedure. Occasionally *algorism* is also used in this generalized meaning, especially in older texts.

Alidhasana: A particular asana, or attitude of legs, in all respects similar to the attitude adopted in drawing the bow. The right leg is outstretched while the left is slightly bent. The attitude should be distinguished from the Pratyalidha attitude in which case the left leg is outstretched while the right is slightly bent and placed behind.

Almagest - Syntaxis by Ptolemy. Was originally titled by him as Syntaxis. The full Greek name was Η Μεγαλη Συνταχιξ (Syntaxis) τηξ Αστρονομια (The Great Synthesis of Astronomy). The present name is a corruption of Arabic Al Kitāb Al Majisti. A manuscript of the *Kitāb al-Majisti*, or *Almagest* (meaning 'the greatest'), was translated into Arabic in the days of Haroun al-Rashid by that caliph's vizier, Yahya, and other translations appeared during the middle part of the 9th century. Study of the *Almajisti* stimulated Arab scholars and incited them to write such original treatises of their own as Al-Farghani's *onthe Elements of Astronomy*, Al-Battani's *on the Movements of the Stars*, or Astronomy. The Almagest in use in Europe subsequent to the fall of Toledo and its treasure of the Library is in reality a completely Arabic document, and we have no way of knowing what proportion of it was originally due to Ptolemy. But the Occidental assumes that everything in the Almagest must be attributed to Ptolemy and that by the same token everything in Indian astronomy is a derivative of Greek Astronomy. But in reality India had reached a pretty sophisticated level of Astronomy by the time Al Biruni visited India in the 10th century CE. It is obvious that the accretions that were made to the text of the Almagest originated from sources other than Greek. We do not know why the orignal work by Ptolemy is never cited as a reference and in fact whether a vulgate copy exists but to claim that everything that is contained in the Almagest, was representative of the state of knowledge in the 2nd century of the CE, and to credit such knowledge to Ptolemy is certainly not a very credible statement in the absence of such a vulgate text.

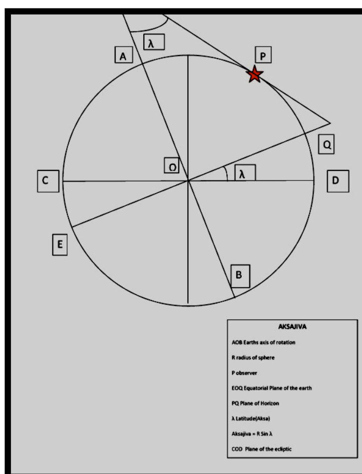


FIGURE 1 ILLUSTRATING ALTITUDE

Altitude – उन्नति, उन्नत ,the angular distance between the horizon and an object in the sky. Angle subtended at the observer by the radius vector connecting a celestial object to an observer on the earth's surface, and the vector's projection, on to the horizontal plane. Objects above/ below the horizon have positive/negative altitudes. See Figure 1

Amanta (see also Pūrnimanta) Indian Lunar calendar where the month begins and ends on **Amāvāsyā** (New Moon)

Amāvāsyā, *अमावस्य* new Moon

Ambedkar, BD, Father's profession: general; religion, Hindu, later Buddhist; previous universities:

Bombay, Columbia, London; number of semesters: 18; school leaving certificate: yes; subject: economics; date of birth: 14.4.1891; place of birth: Mow; home town: Bombay; district: Bombay. So he delightfully upgraded his father's military rank. Dr. Ambedkar registered for economics and not for Indology even though his subsequent interest in Indology is certainly well documented. In his handwritten CV he stated that he knew German well, because he had taken it as a minor at Columbia University: He continued: he would like to mention that the University of Bonn" through the kind help of Prof. Dr. H. Jacobi granted me the opportunity to submit a PhD thesis in case I show adequate performance and I am enrolled for three semesters there". It is not clear in which subject he intended to submit his dissertation, or how he got in touch with Professor Hermann Jacobi (1850-1937), who was the leading German indologist of that era. It is interesting to speculate on the probability of his having got in touch with Hermann Jacobi. In 1913/1914 when Jacobi was visiting professor at Calcutta University, Dr. Ambedkar just left for the US to take up his studies at Columbia University. The contact must have been forged through letters and correspondence, while Dr. Ambedkar was in London, working on his thesis at the London School of Economics. Well, they might have met personally during Dr. Ambedkar's brief visit to Bonn on the occasion of his registration at Bonn University. But that is all speculation. Dr. Ambedkar never took up his studies in Bonn. As he did not sign any lectures or attend any classes, he was taken off the university register on 12.1.1922. Intentions and plans apart, Dr. Ambedkar's project of Sanskrit studies at Bonn University remained unfulfilled. It is an interesting 'what if' to see what course his career might have taken had he achieved mastery over Sanskrit and whether he would have played a more active role in defense of the Indic civilization. Even with a little background in Sanskrit he was perspicacious enough to recognize that the Aryan Invasion Theory was a con job pulled by the colonial overlord to boster his rule over India.

Amṡa अंश 1. Part 2. Numerator of a fraction 3. Degrees in angular measure

Amṡagunana अंशगुणनं ,multiplication of fractions

Amṡabhāgaharanam, अंशभागहरणम division of fractions

Analogy (see also Upamāna) A comparison of the properties of 2 entities, which may reveal the resemblance between the two. It is used in some instances to explain a more difficult concept in terms of a simpler one. The classic example of an analogy is Newton's Apple, where the motion of the heavenly bodies is explained as being governed by the same laws as those of the falling apple. Another example is Āryabhaţa's analogy between the diurnal rotation of the stars in the sky when viewed from the (rotating) earth and the relative motion of the banks of a river when viewed from the boat. (See Prologue, The parable of the lost coin, section on Heliocentric vs. Geocentric paradigms for the exact quote).

Andalusia The Umayyad conquest of Hispania (711–718) began as an Umayyad Caliphate army consisting largely of Berber Northwest Africans recently converted to Islam invaded the Christian Visigoth Kingdom located on the Iberian peninsula (Hispania). Under the authority of the Umayyad Caliph Al-Walid I of Damascus, and commanded by Tariq ibn Ziyad, they disembarked in early 711, at Gibraltar, and campaigned their way northward. Tariq's forces were reinforced the next year by those of his superior, the Emir Musa ibn Nusair.

During the eight-year campaign, most of the Iberian Peninsula was brought under Muslim occupation, save for mountainous areas in the northwest (Galicia and Asturias) and largely Basque regions in the Pyrenees. The conquered territory, under the Arabic name al-Andalus, became part of the expanding Umayyad Empire.

The invaders subsequently moved northeast across the Pyrenees, into present-day France, but were defeated by the Frank Charles Martel (the father of Charlemagne) at the Battle of Tours (Poitiers) in 732. Muslim control of territory in what became France was intermittent and ended in 975.

Angulabhasha, आंगुलभाषा ,the language of metrology

Angula or Angulam, अङ्गुलम् , linear measure, inch 1/24 of a cubit.

Analemma, At noon in a perfect world, the Sun would always be positioned 93 million miles directly over the equator, and the Earth, an unblemished sphere, would rotate evenly on a precisely vertical axis. The seasons would never change. Every day would last as long as every other. And we'd never have the equinoxes and solstices that mark the four quarters of the year.

As it happens, however, the Earth's axis is tilted and, the "slightly eccentric ellipse" of the Earth's orbit around the Sun led astronomers to come up with a consistent way to determine mean time, the time by which we all set our clocks. The natural system is full of variables, and that's without even considering the irregularities of the Earth's rotation, which came to light in the late 19th century.

Thus we have the analemma, the somewhat mysterious looking figure-eight diagram on many globes and maps. The analemma charts where and when the Sun will appear directly overhead in the "torrid zone," between the Tropic of Cancer and the Tropic of Capricorn. The curves of the analemma also mark the solstices and equinoxes. The winter solstice, occurring when the Sun is at its southernmost position in the Torrid Zone, is shown on the most extreme point of an Analemma's lower arc.

The famous picture by Sky & Telescope's Dennis di Cicco records the Sun's position in the sky at the same time of day on 45 different dates **throughout the year. "**In the days before the radio, the analemma was also useful for correcting clocks," says author David Greenhood in his book "Mapping."The days may be dark now but the horizon looks bright: Since the winter solstice marks the shortest day and the longest night of the year, the days will begin to stretch out from now until the summer solstice. Come February and March, when cold temperatures have you fearing that winter will never end, at least the Sun will hang a little longer in the evening sky.

Anomaly, मण्ड केन्द्र ,सीघ्र केन्द्र, the angular separation from the apsides. This measurement is in the plane of the ecliptic. The Sun and the moon have only one correction to the Anomaly, whereas the 5 planets have 2 corrections to the Anomaly, the manda or slow one which derives from the ellipticity of the orbit, and the sighra or fast one which accounts for the relative orbital motion of the planet and the earth about the Sun, causing the apparent retrograde motion of the planet.

FIGURE 3, 4 ANALEMMA PICTURE BY DENNIS DE CICCO

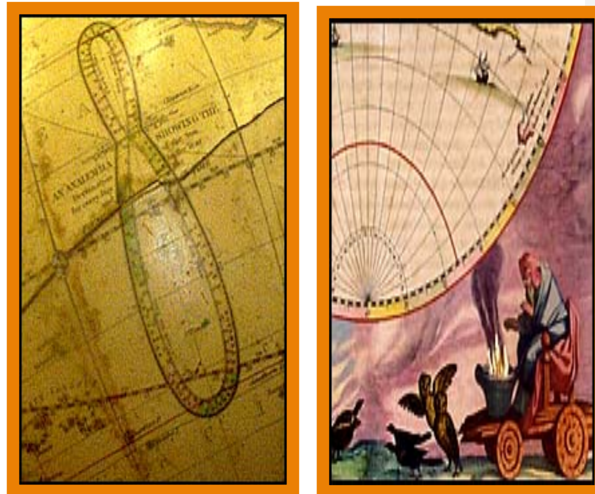




FIGURE 2

Anuloma Direct or Anticlockwise

Anumāna, **अनुमान**, Anumāna, or inference is one of the most important contributions of the system of Meta knowledge known as Nyāya (which translates as Logic).

Anuṣtup अनुष्टुप chandas - A meter in prosody with 32 syllables

Antya-jha The current R sin difference, the Sine difference corresponding to the elementary arc occupied by a planet.

Apabharani (also known as Bharani) one of the 27 Lunar Nakṣatras or mansions, used to locate the planets and the Sun and the Moon during their annual and monthly journey through the skies. See also Nakṣatras. We have picked δ Arietis as the most appropriate junction star in the constellation Aries. It has the traditional name **Botein** which is derived from the Arabic *buţain*, diminutive *baţn* "belly".

δ Arietis is an orange K-type giant with an apparent magnitude of +4.35. It is approximately 168 light years from Earth and its diameter is 13 times that of the Sun.

Apakrama –Declination of a celestial body

Apakramamandala – eclipti**c, also Apamandala, Apamamandala, Apavṛtta** see use of this word in Chapter VIII by Nilakanta

Aparapaksa -full Moon to new Moon period

Āpastamba - आपस्तम्ब, Āpastamba was an ancient Vedic savant, who composed the Sulva Sūtra named after him, credited with approximation for square root of two. His goal was among others to design ritual altars and to conform to the rules of Vāstu Ṣāstra, circa 2500 BCE. Āpastamba predates Āryabhaţa, since Āryabhaţa refers to the Sulva Sūtra in his intellectual tour de force, the Āryabhaţiya. The Sulva Sūtras are part of the Vedāńga, the study of which is recommended prior to the study of the Veda. Chronologically the Sulva Sūtras occur contiguously with the Veda, almost immediately after the completion of the associated Veda. The Sulva Sūtras of interest are Baudhāyana, Kātyāyana, Mānava, and Āpastamba.

Apogee, Aphelion – मण्डोच , the farthest point in the orbit of a planet, the farthest point on an ellipse when measured from the pole. In celestial mechanics, an **apse**, plural *apsides* is the point of greatest or least distance of the elliptical orbit of an object from its center of attraction, which is generally the center of mass of the system. All of the planets in our Solar System move around the Sun in elliptical orbits. An ellipse is a shape that can be thought of as a "stretched out" circle or an oval. The Sun is not at the center of the ellipse, as it would be if the orbit were circular. Instead, the Sun is at one of two points called "foci" (which is the plural form of "focus") that are offset from the center. This means that each planet moves closer towards and further away from the Sun during the course of each orbit. The point in the orbit where the planet is closest to the Sun is called "perihelion". The point where the planet is furthest from the Sun is called "aphelion".

The Earth reaches perihelion in early January each year, and passes through its aphelion point near the start of July. At perihelion, our planet is about 147 million km (91 million miles) from the Sun; it moves outward to around 152 million km (95 million miles) from the Sun at aphelion. The Eccentricity of the orbit is .0167. Earth is about 3% further from the Sun at aphelion than it is at perihelion. Some people have the mistaken impression that our seasons are caused by changes in Earth's distance from the Sun, but this is not the case. Notice how Earth is actually closest to the Sun in the middle of the (Northern Hemisphere's) winter! In fact the time taken by the earth to orbit the Sun from Vernal Equinox to Autumnal equinox is approximately 186.18, and the time taken for the remaining portion of the orbit is 179.06. If the earth was traveling at the same velocity throughout its orbit it would take approximately 182.6^d. Earth's orbit is almost a perfect circle, so the difference between its distance to the Sun at aphelion and at perihelion is slight. Some planets have orbits that are more elongated; astronomers say their orbits have a greater "Eccentricity", which is a technical term for how "stretched out" an orbit is.

Mercury and Pluto have the most eccentric orbits of the planets. Mercury is 52% further from the Sun at aphelion than it is at perihelion, while Pluto is 66% further away at aphelion than at perihelion.
Planets, of course, are not the only objects that orbit the Sun. Many asteroids and comets, and some spacecraft, follow elliptical orbits around the Sun. Any object in such an orbit has both a perihelion and an aphelion point along its orbit. As determined by Kepler and stated in his Second Law of Planetary Motion, the speed of an object in its orbit is fastest at perihelion and slowest at aphelion. The terms perihelion and aphelion apply specifically to objects orbiting the Sun. There are similar terms for the closest and furthest points in orbits around other bodies, such as Earth, the Moon, and other planets and stars. The anomalistic year is slightly longer than the sidereal year. It takes about 112,000 years for the ellipse to revolve once relative to the fixed stars.
Because the anomalistic year is longer than the sidereal year while the tropical year (which calendars attempt to track) is shorter due to the precession of Earth's rotational axis, the two forms of 'precession' add. It takes about 21,000 years for the ellipse to revolve once relative to the vernal equinox, that is, for the perihelion to return to the same date (given a calendar that tracks the seasons perfectly). The dates of perihelion and of aphelion advance each year on this cycle, an average of 1 day every 58 years.
This interaction between the anomalistic and tropical cycle is important in the long-term climate variations on Earth, called the Milankovitch cycles. An equivalent is also known on Mars.
Figure 17, Chapter I illustrates the effects of precession on the northern hemisphere seasons, relative to perihelion and aphelion. Notice that the areas swept during a specific season changes through time. Orbital mechanics require that the length of the seasons be proportional to the swept areas of the seasonal quadrants, so when the orbital Eccentricity is extreme, the seasons on the far side of the orbit may be substantially longer in duration.
Apsides The points in an orbit where two bodies are closest together, (periapsis), and farthest apart (apo-apsis). The line joining these points is called the line of apsides and is the major axis of the orbit.
Amass – Degree
Anumāna – (see inference)
Archaeo-astronomy – the study of the astronomy of ancient cultures… (New Collegiate Dictionary), is also used when Astronomical observations are used to date events in the ancient world
Ardha – half
Ardhajya - half a chord or R-sine
Ardhadhikena – rounding off to the nearest integer
Artha, **अर्थ** Object, purpose, aim, significance, import. Attainment of worldly riches, prosperity, wealth, one of the goals of life prescribed by the Vedics in the Brahma Vidya.
Arjuna – **अर्जुन** The third of the five Pandava princes, whose expertise lies in Archery. He is the protagonist in the Bhagavad Gita, the disciple of his friend and mentor Sri Kṛṣṇa, the avatar of the Lord Himself.

Asanna the word that Āryabhaţa uses to indicate that it is an approximate result. He clearly understands the nature of the irrationality of π when he remarks that no matter how many places we calculate the number, it will still remain approximate, and that it cannot be expressed as a fraction. Pi is a transcendental number. A transcendental number is a number that cannot be expressed in any finite series of either arithmetical or algebraic operations. Pi slips away from all rational methods to locate it. It is indescribable and can't be found. Ferdinand Lindeman, a German mathematician, proved the transcendence of pi in 1882, but AB had a clear concept of irrationality.
Aṡoka (अशोकः, IAST: Aṡokaḥ, (1508 BCE – 1436BCE, conventional dating 304 -232 BCE) was an Indian emperor of the Maurya Dynasty who ruled almost all of the Indian subcontinent from (1472 BCE to 1436 BCE). Often cited as one of India's as well as the world's greatest emperors, Aṣoka reigned over most of present-day India after a number of military conquests. His empire stretched from present-day

Pakistan, Afghanistan in the west, to the present-day Bangladesh and the Indian state of Assam in the east, and as far south as the Brahmagiri in Karnataka. He conquered the kingdom named Kalinga, which no one in his dynasty had conquered starting from Chandragupta Maurya. His reign was headquartered in Magadha (present-day Bihar, India). He was not particularly different from the prevalent tradition in encouraging the practice of all faiths. He was later dedicated to the propagation of Buddhism across Asia and established monuments marking several significant sites in the life of Gautama Buddha, but gave no indication in any of his inscriptions of having abandoned the parent Dharma. Aṣoka in human history is often referred to as the emperor of all ages. Aṣoka is remembered in history as a philanthropic administrator. In the history of India Aṣoka is referred to as *Sāmrāth Chakravartin Aṣoka*- the Emperor of Emperors *Aṣoka*.

Aṡvamedha - **अश्वमेध** A part of Rajasuya ritual performed by emperors to establish their sway over allies and neighboring kingdoms.

Aṡva: Sun (RV 1.164.2; Nirukta 4.4.27)

Aṡvinau

Asta-dikala-pala*:* The Asta-dikpalas are the Guardians of the Directions. These are: Indra—East, *Agni*—South-East, Yama—.South; Nitric—.South-West; Varuna—West Vayu—North-West; Kubera—North; and tisane—North-East. The Asta-dikpala-pata is a panel showing these eight Guardians of the Quarters.

Asterism Dhishnya, a grouping or pattern of stars which does not make a constellation. The stars in an asterism can be smaller part of one constellation or members of more than one constellation.

Astronomer Composers in the Veda – Visvāmitra, Atri, Snuhasepa, Hiranyastupa, Kutsa, Utathya, Dīrghatamas, Kaksivat, Ghosa (Daughter of Dīrghatamas) source, Siddhānta Darpana, p.34, *Chandraṡekhara* Sāmanta.

Asuras, असूर Demons of the Vedic Hindus, linguistically cognate with Ahura (e.g. Ahura Mazda) in Zoroastrianism. Thus, while in Vedic religion the Asuras are demonic, in Zoroastrianism, the Ahura are benign. This inversion also applies to the other class of immortals: where the Vedic *devas* are benevolent, the Zoroastrian *daeva*s are malevolent. It is believed that this resulted in the Great schism between the Vedic Hindus and the followers of Zoroaster (**Zārathūṣtra?**) who migrated west into what is Iran today.

Avasarpiṇī the descending mirror image of Utsarpiṇī, see chapter II for discussion of Yugas

Avidya, **अविद्य** The state of ignorance which needs to be dispelled at the outset, before one can begin the journey in earnest towards self fulfillment and Moksha. 'Ignorance is bliss ' or so the satire goes. Ignorance most certainly is not bliss. It is one of the greatest sins a Hindu can commit. Avidya (parā or aparā) is an unpardonable excuse and as soon as a person determines he/she is in a state of Avidya, they should take steps to remedy the situation.

Aviṡeṣakarman, Aviṡeṣavidhi, asakṛtprakriyā, niṡchalakriya Method of successive approximations.

Aviṡeṣakarṇa – distance obtained by the Method of successive approximations

Aviṡiṣṭa – obtained by the method of successive approximations

Ayana - **अयन** Course or journey; refers to the apparent direction of the Sun's course through the sky, Uttarāyana (north), Dakṣiṇāyana (south); cited in Sankalpam. Going, walking; road, path, way. Used in astronomy for advancing, precession; the Sun's progress northward or southward, from one solstice to the other, is an ayana or half-year, two ayanas making one year. Also the equinoctial and solstitial points, the term for the solstice being ayananta. Finally, ayana signifies circulatory courses or circulations, as of the universe.

Ayanāmṡa – **अयनाम्श** Ayanāmṡa is the Sanskrit term for the longitudinal difference between the tropical or Sāyaṇa and sidereal or Nirāyana Zodiacs. It is defined as the angle by which the sidereal ecliptic longitude of a celestial body is less than its tropical ecliptic longitude.

The sidereal ecliptic longitude of a celestial body is its longitude on the ecliptic defined with respect to the "fixed" stars.

The tropical ecliptic longitude of a celestial body is its longitude on the ecliptic defined with respect to the vernal equinox point.

Since the vernal equinox point precesses westwards at a rate of 50".29 per year with respect to the fixed stars, the longitude of a fixed body defined with respect to it will increase slowly. On the other hand, since the stars "do not move" (this ignores the effect of proper motion) the longitude of a fixed body defined with respect to them will never change.

Ayanachalana - अयन चलन See Precession of the equinoxes (synonym krāntipātagati)

Ayanantha - Solstice

Ayanabhāga - Amount of precession. i.e. arc of the ecliptic lying between the vernal equinox and the Indian zero point, synonym Ayanāmśa

Āchārya, आचार्या a spiritual guide or teacher. See Sankarācharya

Ādisesha*:* God Vishnu.

Ādi, **आदि** first, primordial as in Ādi Sankara

Āditi, **आदिति** In Hinduism, Āditi (Sanskrit - limitless) is a goddess of the sky, consciousness, the past, the future and fertility. She is an ancient goddess, mother of Agni and the Ādityas with Kashyapa. She is associated with cows, a very holy animal in Hindu beliefs. Āditi is the daughter of Daksha and Veerni. She gave birth to the Devas who were beautiful, intelligent and pious to the Almighty. Although the goddess Āditi is mentioned nearly eighty times in the RV, it is difficult to get a clear picture of her nature. She is usually mentioned along with other gods and goddesses, there is no one hymn addressed exclusively to her, and unlike many other Vedic deities, and she is not obviously related to some natural phenomenon. Compared to Usha and Prithvi, her character seems ill defined. She is virtually featureless physically. Perhaps the most outstanding attribute of Āditi is her motherhood. She is preeminently the mother of the Ādityas, a group of 7 or 8 gods which include Mitra, Āryamān, Bhaga, Varuna, Daksha and Ansa.

(2.27.1) Āditi is also said to be the mother of the great god Indra, the mother of kings (2.27), and the mother of gods (1.113.19). Unlike Prithvi, however, whose motherhood is also central to her nature, Āditi does not have a male consort in the Ṛg-veda. As a mothering presence, Āditi is often asked to guard the one who petitions her (1.106.7; 8.18.6) or to provide him or her with wealth, safety, and abundance (10.100; 1.94.15).

Āditya, *आदित्य* In Hinduism, the Ādityas are a group of solar deities, sons of Āditi and Kashyapa. In the RV, they are seven deities of the heavens; chief of these being Varuna, followed by Mitra, Āryaman, Bhaga, Daksha, and Ansa, the seventh Āditya was probably the Sun, Sūrya, or Savitar. As a class of gods, the ṚgVedic Ādityas were distinct from the Visvedevas. In the Yajurveda (Taittiriyā Saṃhitā), their number is given as eight. In the Brāhmaṇas, their number is expanded to twelve, corresponding to the twelve months: Ansa, Āryaman, Bhaga, Daksha, Dhatri, Indra, Mitra, Ravi, Savitar, Sūrya , Varuna, Yama Āditya in the (Chāndogya-Upanishad) is also a name of Vishnu, in his Vāmana (dwarf) Avatar. See the dictionary of Hindu Lore and Legend (ISBN 0500510881) by Anna Dhallapiccola. Āditya is an also a title used by the Solar Dynastic Kings.

Āgama, *आगम* -Ancient Sanskrit religious text, scriptural truth, or verbal means of knowledge: a traditional doctrine or system which commands faith

Āraṇyakas, *आरण्यक* The third part of each of the Vedas (after Saṃhitās, and Brāhmaṇas) elaborating various spiritualistic practices for forest dwelling initiates into spirituality. The Āraṇyakas (Sanskrit Āraṇyaka) are part of the Hindu Śruti; these religious scriptures are sometimes argued to be part of

either the Brāhmaṇas or Upanishads. The name translates to "the forest books", meaning, treatises for hermits or sadhus living in the wilderness. This contrasts with the Grhya Sūtras, treatises intended for domestic life. Their language is early Classical Sanskrit, and together with the bulk of the Upanishads, the Āraṇyakas form the basis of Vedanta,

Ārati *आरति*-A ritual in which a plate or thali with a deepa(oil lamp) and other items of ritual purification such as flowers, incense, kumkum and turmeric, are waved at least 3 times clockwise around a venerated person or object. Sometimes the plate may contain just water with kumkum dissolved in it.

Ārjava, **आर्जव** straightforwardness at all times

Āryabhaţa , **आर्यभठ** ancient Indian mathematician the astronomer laureate of India, who lived in the Post Vedic period. His dating is controversial but could be as early as 2500 BCE and if so is contemporaneous or even predates Babylonian mathematicians. Āryabhaţa was the author of the Āryabhaţīy*a* and the Āryabhaţa Siddhānta, which, achieved a major following in Kerala and, through the Sāsānian dynasty (224–651) of Iran, had a profound influence on the development of Islamic astronomy. Its contents are preserved to some extent in the works of *Varāhamihīra* (flourished c. 123BCE), Bhāskara I (flourished c.?), and others. It is one of the earliest astronomical works to assign the start of each day to midnight. Āryabhaţa explicitly mentioned that the earth rotates about its axis, thereby causing what appears to be an apparent westward motion of the stars. Āryabhaţa also mentioned that reflected Sunlight is the cause behind the shining of the Moon. Āryabhaţa's followers were particularly strong in Kerala, where his principles of the diurnal rotation of the earth, among others, were followed and resulted in the adoption of the heliocentric system, as a predominant paradigm during the 15th and 16th century, independently of the Copernican revolution.

Ārya, **आर्य** is an adjective that qualifies a noun meaning noble such as in Ārya Putr, noble son, or noble prince characterizing the behavior of the person. It has no racial connotation.

Āryan, **आर्यन्** A term connoting the fictitious Aryan race, sees also Vedics. Vedic should not be used synonymously with the word Aryan which has a racial connotation. Ārya is purely a behavioral adjective and nothing more.

Āryan Race - A fictitious classification without any scientific basis used by the Europeans to distinguish themselves from the Semitic speaking people of the world. A word that has been foisted upon the Vedics who used the adjective Ārya meaning of noble behavior. There was no racial connotation as there is now in Europe.

Āṣāḍhā: The 20th (Uttara) and 21st (Pūrva) Nakṣatra in the Lunar Zodiac or Nakṣatra system

Āsana: The word in Sanskrit may mean a seat or an attitude exhibited in the lower limbs. The word Padmāsana means the seat of lotus. Similarly, Sinhāsana means any easy attitude of sitting. It may be the Paryankāsana, the Lalitāsana, or the Ardha-paryankāsana. In fact, in the Sadhanamala, the word Sukliasana is not used in a technical sense. When used in a technical sense asana is of various kinds, such as the Paryankāsana, Vajraparyankāsana, Lalitāsana, Ardha-paryankāsana, Bhadrāsana, Ahidhāsana, Pratyahidhāsana, etc.

B

Bandopadhyay, Rakhal Das (aka Banerjee, 1885- 1930) Rakhaldas Bandopadhyay was born on 12 April 1885 in Berhampore of Murshidabad district to Matilal and Kalimati. Rakhaldas graduated from Presidency College, Kolkata with Honors in History in 1907 and obtained his MA in History from the Calcutta University in 1910. Rakhaldas joined the Indian museum in Calcutta as an Assistant to the Archaeological Section in 1910. He joined the Archaeological Survey of India as Assistant Superintendent in 1911, and was promoted to the rank of Superintending Archaeologist in 1917. After teaching at the

University of Calcutta, he later joined the Banaras Hindu University in 1928 and held the post till his premature death in 1930.

Bayt al Hikmah, the House of Wisdom, The **House of Wisdom** was a library and translation institute in Abbassid-era Baghdad, Iraq. It was a key institution in the Translation Movement and considered to have been a major intellectual center of the Islamic Golden Age. The House of Wisdom acted as a society founded by Abbasid caliphs Haroun al-Rashid and his son al-Ma'amun who reigned from 813-833 CE. Based in Baghdad from the 9th to 13th centuries, many of the most learned Muslim scholars were part of this excellent research and educational institute. The term *house of wisdom* is a direct translation of Persian Sassanians' designation for a library. It was modeled on that of the Sassanians, had the purpose of translating books from Persian to Arabic, and also of preservation of translated books.

In the reign of al-Ma'amun, observatories were set up, and The House was an unrivalled centre for the study of humanities and for sciences, including mathematics, astronomy, medicine, chemistry, zoology, and geography. Drawing on Persian, Indian and Greek texts—including those of Pythagoras, Plato, Aristotle, Hippocrates, Euclid, Plotinus, Galen, Sushruta, Charaka, Āryabhaţa, Socrates and Brahmagupta—the scholars accumulated a great collection of world knowledge, and built on it through their own discoveries. Baghdad was known as the world's richest city and centre for intellectual development of the time, and had a population of over a million, the largest in its time. The great scholars of the House of Wisdom included Al-Khwarizmi, the "father" of algebra, which takes its name from his book Kitāb al-Jabr.

Bhagana - is the completion of an orbit of revolution of a planet, see Yuga Bhagana

Bhagola – the celestial sphere

Bhagola Madhya - the centre of the celestial sphere

Bhakti Yoga, भक्ति An approach to worship and spiritual practice in the Hindu tradition characterized by personal devotion to a divinity , often mediated by a holy person or teacher somewhat akin to the relationship with Christ among certain sects and adherents of Christianity

Bhartṛhari, **भर्तृहरि** - Bhartṛhari along with *Pāṇini* and Patanjali's who preceded him by several centuries is regarded as one of the main contributors to the field of linguistics in ancient India. He introduced the notion of Shabda tattva or Shabda Pramāṇa, namely "the notion of the original word (Shabda) as transcending the bounds of spoken and written language and meaning. Understood as Shabda tattva-the "word principle," this complex idea explains the nature of consciousness, the awareness of all forms of phenomenal appearances, and posits an identity obtains between these, which is none other than Brahman. It is thus language as a fundamentally ontological principle that accounts for how we are able to conceptualize and communicate the awareness of objects. The metaphysical notion of Shabda Brahman posits the unity of all existence as the foundation for all linguistically designated individual phenomena.

Bhāṡya, *भाश्य* Commentary on a celebrated or scriptural work (e.g. Adi Sankara's **Bhāṡya** on the Bhagavad Gita), Scholia

Bhāṡya kāra commentator, scholiast

Bhāchakra – Circle of Asterisms

Bhagana - Revolution

Bhūdivas - A terrestrial day

Bhūgola - The sphere of the earth

Brahmachārya - Or student life, when a boy lives with his teacher (Guru) and receives both religious and secular instruction. The youth is trained in self control, and acquires such virtues as chastity, truthfulness, faith, and self surrender.

Brāhmaṇa, ब्राह्मणं-the correct pronunciation includes a short 'a' vowel at the end, the first 'a' is a long vowel while the second is a short one. The literal meaning is one who attains Brahman is a Brāhmaṇa -

Brahavit Brahaiva bhavati - is the Śruti and is the strict definition of a Brāhmaṇa. In this day and age it is difficult to fathom in a short period of time whether a particular person has realized Brahman or not. In such a circumstance one looks for adherence to the ethical values of the Hindu and whether the person has the qualities mentioned therein. One of the 4 Varna's of society possessing a predominantly sātvic guna amongst the three Guṇa (Traigunya) rajas, tamas and satva. The Sanātana Dharma strove to inculcate a meritocracy and recognizes everybody is not capable of meeting the same challenges. It is not a one size fits all ideology. The Dharma also recognizes there is diversity in the human species that not everybody can become a doctor or a star football player and that the person by reason of his Guṇa may not have the inclination, fortitude and desire to put in the long years of training necessary to become a doctor. These differences are not necessarily related to ones appearance or even heredity but have to do with whether a person has the discipline, the single minded focus and fortitude to undertake the arduous task of becoming a doctor or a Vedic priest or a star football player. Every fetus has the potential for fulfillment and Moksha but whether every single person rises to the demands of the tradition is a different matter, despite the fact that it is within the reach of each and every individual. In the modern era the Brāhmaṇa has adapted himself to the rigors and demands of a predominantly technological milieu and has filled many roles such as Doctor, Engineer, lawyer, Journalist, politician, think tank adviser, Professor, corporate executive, in addition to being a priest. Even so, the priestly Brāhmaṇa community remains one of the poorest in India today.

Brāhmaṇa, ब्राह्मणं texts associated with each Veda

Brahmavidya, or Parāvidya (metaphysics meta-knowledge or higher knowledge) is the vehicle for attaining Moksha in the path known as Jnana Yoga and Yogasastra (the means to attain the same) is the practical discipline needed to attain Brahmavidya.



Brahmanism - Brahmanism is an ersatz terminology used to describe Sanātana Dharma that has become popular in certain circles in the west. It is clear that the Dharma is a whole family of beliefs and Darŝanas. It has been thus since a very long time. The Vedic texts have survived several millennia of wars and natural disasters, but it is quite possible other texts have been lost. It has never been the contention of Hindus that the Vedas are the only canon to have originated in the Indian subcontinent. But it is clear that they are among the few to survive over the millennia. Furthermore the implication that Brāhmaṇas had exclusive control over the content and practice of the faith is demeaning and insulting to the Sanātana Dharma which has had a long line of Riṣis and Sages who have expounded on the faith few of whom were born Brāhmaṇas. Belief systems

that did not subscribe to the Vedic canon have been extant for a very long time and have been known as Nāstik Dharma and include among others Chārvāka, Jainism, and Buddhism. It is therefore unnecessary to invent a new word Brahmanism to describe an ancient faith which has a perfectly good name namely Sanātana Dharma. To use the word Rabbi-ism to describe the faith taught in Synagogues simply would not be accepted but for some strange reason it is this peculiar word that has been foisted by the Occidental on the Indic to give the impression that it was only an elite few who practiced it.

Brahmi script ब्रह्मि Brahmi is a "syllabic alphabet", meaning that each sign can be either a simple consonant or a syllable with the consonant and the inherent vowel /a/. Other syllabic alphabets outside of South Asia include Old Persian and Meroïtic. However, unlike these two systems, Brahmi (and all subsequent Brahmi-derived scripts) indicates the same consonant with a different vowel by drawing extra strokes, called *matras*, attached to the character. Ligatures are used to indicate consonant clusters. The Brahmi script was first deciphered by James Prinsep although I find it difficult to believe that they could not find a single Indian who was capable of deciphering the Brahmi script. The Brahmi script is one of the most important writing systems in the world by virtue of its time depth and influence. It represents the earliest post-Indus corpus of texts, and some of the earliest historical inscriptions found in India. Most importantly, it is the ancestor to hundreds of scripts found in South, Southeast, and East Asia. This elegant script appeared in India most certainly by the 5th century BCE, but the fact that it had many local variants even in the early texts suggests that its origin lies further back in time. There are several theories on to the origin of the Brahmi script. The first theory of the Occidentals is that Brahmi has a West Semitic origin (in keeping with their overall philosophy that nothing original emanated from India). Another theory, from a slightly different school of thought, proposes a Southern Semitic origin. Finally, the third theory holds that the Brahmi script came from Indus Valley Script. At least in my personal opinion, this is the most likely origin of Brahmi. In fact the very name Brahmi suggest it was developed along the banks of the River Sarasvati. The chart in Figure 6 is the basic script. There are many variations to the basic letter form. And an example of strokes added to indicate different vowels following the consonants /k/ and /l/.

FIGURE 5 THE BRAHMI SCRIPT

C

Cardinal Points in a year refer to the 2 equinoxes and the 2 solstices.

Cardinal and Ordinal numbers: In linguistics, ordinal numbers are the words representing the rank of a number with respect to some order, in particular order or position (i.e. *first*, *second*, *third*, etc.). Its use may refer to size, importance, chronology, etc. They are adjectives.

They are different from the cardinal numbers (*one*, *two*, *three*, etc.) referring to the quantity.

Ordinal numbers are alternatively written in English with numerals and letter suffixes: 1st, 2nd or 2d, 3rd or 3d, 4th, 11th, 21st, 477th, etc. In some countries, written dates omit the suffix, although it is nevertheless pronounced. For example: 4 July 1776 (pronounced "the fourth of July "); July 4, 1776, ("July fourth"). When written out in full with "of", however, the suffix is retained: the 4th of July. In other languages, different ordinal indicators are used to write ordinal numbers. Cardinal numbers are normally used when you; 1. Count things: Example: I have two brothers. Example: There are thirty-one days in January. 2. Give your age: Example: I am thirty-three years old. Example: My sister is twenty-seven years old. 3. Give your telephone number: Example: Our phone number is two-six-three, three-eight-four-seven. (481-2240).

4. Give years: Example: She was born in nineteen seventy-five (1975). Example: America was discovered in fourteen ninety-two. The system of numbering years (as in the Gregorian calendar-2 BC, -1 BC, 1 AD, and 2 AD) makes sense only as a cardinal Number. Five years would have elapsed from the start of -2 BC to the end of 2 AD, if we insisted on ordinality. The Indic calendrical system uses ordinal numbers, since year 1 implies, 1 year has elapsed already

Caste Derived from Portuguese Casta, Caste has a meaning quite distinct from Varna which has been accepted as being part of the tradition. Caste according to the Portuguese means a race or a breed. Varna makes no such distinction and to ascribe racial motivations for a system based on division of labor depending on individual inclinations and which is a meritocracy to boot is totally unconscionable, but that is exactly what the colonial power did with great success. The Sanātana Dharma makes no apologies for being a meritocracy based on competency and character and it is only after the advent of colonial rule that it took on the character of a racial and ethnic division based on birth. It is a tribute to the tenacity and persistence of the British that their viewpoint has prevailed and has been internalized by the Indic population for the most part. Yet it behooves those of us who know better to keep reminding everybody that the colonial viewpoint reflects a conjured up reality that has no relation to a core value nor is it derived from core beliefs held since antiquity. See also Varnāshrama dharma.

Chakravartin, चक्रवर्तिन् a Sanskrit bahuvrīhi (compound word), literally "whose wheels are moving", in the sense of "whose chariot is rolling everywhere without obstruction". It can also be analyzed as an 'instrumental bahuvrīhi: "through whom the wheel is moving", in the meaning of "through whom the Dharmachakra (Wheel of Dharma) is turning" (most commonly used in Buddhism and Hinduism); Pali *chakkavatti*, (also interpreted as "for whom the Wheel of Dharma is turning") is a term used in Indian religions for an ideal universal ruler, who rules ethically and benevolently over the entire world. Such a ruler's reign is called *sarvabhauma*. The notion of a Chakravartin in Ancient India did not have the same connotation as that of an Emperor**.** His role was not merely that of being the first among equals, but one who upheld the Dharma. (see Figure 7, Appendix B).

Chāpa – arc

Chāpakhanda – a unit of an arc

Calendar A calendar is an organized attempt to depict various units of time, in order that one may plan activities over a certain period. There are over 40 calendars in use throughout the world today. However, the number of distinct categories of calendars is far fewer.

Celestial (Equatorial) Coordinate System: the most commonly used astronomical coordinate system for indicating the positions of stars or other celestial objects on the celestial sphere . The celestial sphere is an imaginary sphere with the observer at its center. It represents the entire sky; all celestial objects other than the earth are imagined as being located on its inside surface. If the earth's axis is extended, the points where it intersects the celestial sphere are called the celestial poles; the north celestial pole is directly above the earth's North Pole, and the south celestial pole directly above the earth's South Pole. The great circle on the celestial sphere halfway between the celestial poles is called the celestial equator; it can be thought of as the earth's equator projected onto the **celestial sphere**. It divides the celestial sphere into the northern and southern skies. An important reference point on the celestial equator is **the vernal equino**x, the point at which the Sun crosses the celestial equator in March. To designate the position of a star, the astronomer considers an imaginary great circle passing through the celestial poles and through the star in question. This is the star's **hour circle**, analogous to a meridian of longitude on earth. The astronomer then measures the angle between the vernal equinox and the point where the hour circle intersects the celestial equator. This angle is called the star's **right ascension** and is measured in hours, minutes, and seconds rather than in the more familiar degrees, minutes, and seconds. (There are 360 degrees or 24 hours in a full circle.) The right ascension is always measured eastward from the vernal equinox. Next the observer measures along the star's hour circle the angle between the celestial equator and the position of the star. This angle is called the **declination** (Apakrama) of the star and is measured in degrees, minutes, and seconds north or south of the celestial equator, analogous to latitude on the earth. Right ascension and declination together determine the location of a star on the celestial sphere. The right ascensions and declinations of many stars are listed in various reference tables published for astronomers and navigators. Because a star's position may

change slightly (see proper motion and precession of the equinoxes), such tables must be revised at regular intervals. **By definition, the vernal equinox is located at right ascension 0 h and declination 0°.**

Celestial equator, **नाडीवृत** Nadivruth, Nadivalaya, Ghatikmandala, Nadikmandala - The great circle on the celestial sphere halfway between the celestial poles is called the celestial equator.

Celestial Pole

Chandramāsa – Lunar month

Colure (Sk. *Dhruvapottavrtta*)A great circle of the celestial sphere through the celestial poles and either the equinoxes or solstices, called respectively the equinoctial colure or the solstitial colure.

Commensurable an expression used of orbital periods that are in proportion to one another by exact fractions, such as one half, one third, or three fourths.

Conjunction in astronomy means the alignment of two celestial bodies as seen from the earth. Conjunction of the moon and the planets is often determined by reference to the sun. When a body is in conjunction with the sun, it rises with the sun, and thus cannot be seen; its elongation, in astronomy, the angular distance between two points in the sky as measured from a third point. The elongation of a planet is usually measured as the angular distance from the sun to the planet as measured from the earth.

The moon is in conjunction with the sun when it is new; if the conjunction is perfect, an eclipse of the sun will result. Mercury and Venus, the two inferior planets, have two positions of conjunction. When either lies directly between the earth and the sun, it is in inferior conjunction; when either lies on the far side of the sun from the earth, it is in superior conjunction.

D

Dakṣiṇāyana, Pitruana - The southward journey of the Sun towards the Winter solstice, from its northernmost point during the Summer solstice usually identified as Dakṣiṇāyana Punyakāla on July 16.

Declination –Krānti, क्रांति, Angular distance of a celestial object north or south of the celestial equator

Desantara – longitude of a place, measured relative to a standard or prime meridian or colure

Dasha - दशन् Ten as in Dashāvatara, the ten Avatars of Vishnu

Dashami - दशमि The tenth day of the Lunar fortnight or Pakṣa, occurs twice a month

Decimal system - see also place value system, decimal system [Latin= of tenths], numeration system based on powers of 10. A number is written as a row of digits, with each position in the row corresponding to a certain power of 10. A decimal point in the row divides it into those powers of 10 equal to or greater than 0 and those less than 0, i.e., negative powers of 10. Positions farther to the left of the decimal point correspond to increasing positive powers of 10 and those farther to the right to increasing negative powers, i.e., to division by higher positive powers of 10. For example, 4,309=(4x10**3)+(3x10**2)+(0x10**1)+(9x10**0)=4,000+300+0+9, and 4.309=(4x10**0)+(3x10**-1)+(0x10**-’2)+(9x10**-’3)=4+3/10+0/100+9/1000.

It is believed that the decimal system is based on 10 because humans have 10 fingers and so became used to counting by 10s early in the course of civilization. The decimal system was introduced into Europe c.1300. It greatly simplified arithmetic and was a much-needed improvement over the Roman numerals, which did not use a positional system. A number written in the decimal system is called a decimal, although sometimes this term is used to refer only to a proper fraction written in this system and not to a mixed number. Decimals are added and subtracted in the same way as are integers (whole numbers) except that when these operations are written in columnar form the decimal points in the column entries and in the answer must all be placed one under another. In multiplying two decimals the operation is the same as for integers except that the number of decimal places in the product, i.e., digits to the right of the decimal point, is equal to the sum of the decimal places in the factors; e.g., the factor 7.24 to two decimal places and the factor 6.3 to one decimal place have the product 45.612 to three decimal places. In division, e.g., 4.32 /12.8 where there is a decimal point in the divisor (4.32), the

point is shifted to the extreme right (i.e., to 432.) and the decimal point in the dividend (12.8) is shifted the same number of places to the right (to 1280), with one or more zeros added before the decimal to make this possible. The decimal point in the quotient is then placed above that in the dividend, i.e., 432|1280.0 zeros are added to the right of the decimal point in the dividend as needed, and the division proceeds the same as for integers. The decimal system is widely used in various systems employing numbers. The metric system of weights and measures, used in most of the world, is based on the decimal system, as are most systems of national currency.

Deferent, Kakṣyāvṛtta- the circumference of the deferent circle

Deferent Circle – Geocentric circle in the epicyclic theory and the concentric in the eccentric theory

Devanagari, देवनागरी the script in which the Sanskrit language has usually been written on. It has the same syllabic structure as Brahmi, the ancestor script of India. Appendix C provides the basic shapes of the Sanskrit script.

Dharma - one of the four kinds of human aspirations, which are dharma, artha, kāma, and moksha. dharma: "Righteous living." The fulfillment of virtue, good works, duties and responsibilities, restraints and observances - performing one's part in the service of society. This includes pursuit of truth under a guru of a particular Parampara and sāmpradāya. Dharma is of four primary forms. It is the steady guide for artha and Kama.

Dharma (Baudhik) - A central notion of Buddhism, used in various contexts;

1. The cosmic law, the great norm, underlying our world; above all the law of karmically determined rebirth.

The teaching of the Buddha, who recognized and formulated this law; thus the teaching expresses the universal truth. The Dharma in this sense existed before the birth of the historical Buddha, who is no more than a manifestation of it. This is the Dharma in which the Buddhist takes refuge.

Norms of behavior and ethical rules. Manifestation of reality, of the general state of affairs.

Dhruvaka In the Indic literature this is referred to as Polar Longitude, is expressed in degrees

Dhvani the uttered syllables of a word

Digvijaya: Universal conquest undertaken usually with a view to perform the horse-sacrifice ceremony, which is indicative of Universal Supremacy.

Dikpala: A regent of a Quarter. These are eight in number.

Dhruva: celestial pole

Dhruvaka: Polar Longitude. Adjective of Dhruva (fixed immovable) by which the poles of the heavens are designated. It is the longitude of a star as referred to the ecliptic by a circle from the pole. Note that since this does not pass through the ecliptic pole, this circle will not intersect the ecliptic at right angles. It is Burgess, who terms the distance of this point from the vernal equinox as polar longitude, to distinguish it from Ecliptic longitude. See also Vikshepa.

Dhruva Tara - celestial Pole star (currently Polaris is the closest to the celestial pole)

Dhruvapotavṛtta – Great circle passing though the celestial pole and the object in the sky (Colure or meridian.

Dīrghatamas – दीर्घतमस Dīrghatamas was one of the Angirasa Riṣis, the oldest of the Rishi families, and regarded as brother to the Riṣi Bharadvaja, who is the seer of the sixth book of the RV. Dīrghatamas is a Vedic sage famous for his philosophical verses in the RV. He is author of Suktas (hymns) 140 to 164 in the first Mandala (section) of the RV Saṃhitā. Dīrghatamas is also the chief predecessor of the Gotama family of Riṣis that includes Kakṣivan Gotama, Nodhas and Vamadeva (seer of the fourth book of the RV), who along with Dīrghatamas account for almost 150 of the 1000 hymns of the RV. His own verses occur frequently in many Vedic texts, a few even in the Upanishads.

He was the reputed purohit or chief priest of King Bharata (Aitareya Brāhmaṇa VIII.23), one of the earliest kings of the land, from which India as Bharata (the traditional name of the country) was named.

There is an interesting story about the birth of Dīrgatamas**.** Bhishma tells the story of the birth of Dīrghatamas in the MBH (book1, Adi Parva, CIV): "There was in olden days a wise Rishi of the name of Utathya. He had a wife of the name Mamata whom he dearly loved. One day Utathya's younger brother Brihaspati, the priest of the celestials, endued with great energy, approached Mamata. The latter, however, told her husband's younger brother--that foremost of eloquent men--that she had conceived from her connection with his elder brother and that, therefore, he should not then seek for the consummation of his wishes. She continued, 'O illustrious Brihaspati, the child that I have conceived hath studied in his mother's womb the Vedas with the six Angas. How can then this womb of mine afford room for two children at a time? Therefore, it behoveth thee not to seek for the consummation of thy desire at such a time. Thus addressed by her, Brihaspati, though possessed of great wisdom, succeeded not in suppressing his desire. The child in the womb then addressed him and said, 'O father, cease from thy attempt. There is no space here for two. O illustrious one, the room is small. I have occupied it first. It behoveth thee not to afflict me.' But Brihaspati without listening to what that child in the womb said, sought the embraces of Mamata possessing the most beautiful pair of eyes. And the illustrious Brihaspati, beholding this, became indignant, and reproached Utathya's child and cursed him, saying, 'Because thou hast spoken to me in the way thou hast at a time of pleasure that is sought after by all creatures, perpetual darkness shall overtake thee.' And from this curse of the illustrious Bṛshaspati Utathya's child who was equal unto Brihaspati in energy, was born blind and came to be called Dīrghatamas (enveloped in perpetual darkness). And the wise Dīrghatamas, possessed of knowledge of the Vedas, though born blind, succeeded yet by virtue of his learning, in obtaining for a wife a young and handsome Brāhmaṇa maiden of the name of Pradweshi. And having married her, the illustrious Dīrghatamas, for the expansion of Utathya's race, begat upon her several children with Gautama as their eldest."

Dīrghatamas is famous for his paradoxical apothegms. His mantras are enigmas: "He who knows the father below by what is above, and he who knows the father who is above by what is below is called the poet."

The Asya Vāmasya (RV 1.164) is one of the sage's most famous poems. Early scholars (such as Paul Deussen in his Philosophy of the Upanisads) tried to say that the poems of Dīrghatamas were of a later nature because of their content, but this has no linguistic support which has been argued by modern Sanskrit scholars (such as Dr. C. Kunhan Raja in his translation of the Asya Vāmasya Hymn). The reason earlier western scholars believed it was of a later origin is because of the monist views found there. They believed that early Vedic religion was pantheistic and a monist view of god was presumed to have evolved later in the Upanisads- but the poems of Dīrghatamas (1.164.46) which say "there is One Being (Ekam Sat) which is called by many names" proves this idea to be incorrect.

Divyabda a divine year, equals 360 civil years

Dravidian languages - An unverifiable hypothesis made to distinguish the languages of the south of India (Dravida) from those of the north. In reality, a Telugu (Kannada, Tamil, or Malayalee) speaking Pandit, ostensibly a Dravidian language can understand and chant Sanskrit far more readily than even an accomplished scholar in Sanskrit in the west. This despite the putative similarity between the European languages and Sanskrit.

Drkchaya - Parallax

Druhyu - One of 5 clans namely Anus, Druhyus, Turvashas, Puru, Yadu, the sons of Yayati. Druhyu is the 3rd son of Yayati. His dynasty is listed in Chapter 23 of the Bhāgavata Purāṇa. The descendants of Druhyu eventually went on to become Zarathushtrans, followers of Zarathushtra and subsequently formed the Āryamanush (Greek corruption Achaemenid) empire, e.g. Darius = Druhyu (Sanskrit) Daryavahyu (Persian). Some of the ancient Persian kings belonging to the *Ārya*manush Dynasty

Haxamanish or ACHAEMENES, first King of Persia, was mythical.

Teispes c. 7th century BC. (This is the Greek version of the name)

Kurash I , Kuru (or CYRUS I) c. late 7th Century BC, son of Teispes.
Ariaramnes ca. late 7th century BC, son of Teispes.
Kambujia I (or CAMBYSES I) ? - 559 BC, son of Kurash I.
Kurash II (or CYRUS II) 559 - c. 550 BC when he became King of Kings, son of Kambujia I.
For other Old Persian Sanskrit names see for instance,
http:/indicstudies.us/Archives/Linguistics/Persian names. I recommend all the readers of Indic origin (and others) use Sanskritic names for Iranian kings. That will force us into a thought process that they were all a part of the Vedic civilization.
Dvarapala: *Guardian at the entrance*

E

Earliest Mention of the Rāśi (Solar Zodiac): Some scholars have claimed that the Babylonians invented the Zodiac of 360 degrees around 700 BCE, perhaps even earlier. Many claim that India received the knowledge of the Zodiac from Babylonia or even later from Greece. However, as old as the RV, the oldest Vedic text, there are clear references to a chakra or wheel of 360 spokes placed in the sky. The number 360 and its related numbers like 12, 24, 36, 48, 60, 72, 108, 432, and 720 occur commonly in Vedic symbolism. It is in the hymns of the Riṣi Dīrghatamas (RV I.140 - 164) that we have the clearest such references.

Eccentricity , a measure of **the** degree of ellipticity of an orbit. The Eccentricity of an ellipse ranges between 0 (for a circle) and 1 for a parabola. Eccentricity is calculated by dividing the distance between the two foci by the length of the semi major axis.

Eclipse - The passage of one astronomical body into the shadow of another, but this term is usually applied to the passage of the Moon in front of the Sun, called a solar eclipse. A Lunar eclipse is when the Moon passes into the Earth's shadow, which can only happen during a full Moon.

Eclipse Year (YE) is the period between the earth and Lunar orbit planes node crossings. (Also known as Nodal Year?)

Ecliptic krāntivṛtta क्रांतिवृत्त - the great circle on the celestial sphere that lies in the plane of the earth's orbit (called the plane of the ecliptic). Because of the earth's yearly revolution around the Sun, the Sun appears to move in an annual journey through the heavens with the ecliptic as its path. The ecliptic is the principal axis in the ecliptic coordinate system. The two points at which the ecliptic crosses the celestial equator are the equinoxes. The obliquity of the ecliptic is the inclination of the plane of the ecliptic to the plane of the celestial equator, an angle of about 24°. The constellations through which the ecliptic passes are the constellations of the Zodiac .

Ekādasi, एकादसि Ekadasi is the eleventh Lunar day (Tithi) of the Śukla (waxing) or Kṛṣṇa (waning) Pakṣa (fortnight) respectively, of every Lunar month in the Hindu calendar (Panchānga). In Hinduism and Jainism, it is considered a spiritually beneficial day. Scriptures recommend observing an (ideally waterless) fast from sunset on the day prior to Ekadasi until 48 minutes after sunrise on the day following Ekadasi. Ekadasi is a Sanskrit word, which means 'the eleventh'. It refers to the eleventh day of a fortnight belonging to a Lunar month. There are two fortnights in a Lunar month—the bright and the dark. So, Ekadasi occurs twice in a month, in the bright fortnight and the dark fortnight. The special feature of Ekadasi, as most people know it, is a fast, abstinence from food. This is how it is usually understood. In fact, the fast is only a practical expression and a symbol of something else that we are expected to do, which is of special significance to our personality.

Epagomenal days – for example adding 5 epagomenal days to 360^d of a Lunar year, as in the Julian calendar. This was done in Egypt and in India among others.

Ephemeris, (*Plural* **ephemerides**) A table giving the coordinates of a celestial body at specific times during a given period. Ephemerides can be used by navigators to determine their longitude while at sea

and by astronomers in following objects such as comets. The use of computers has allowed modern ephemerides to determine celestial positions with far greater accuracy than in earlier publications. An **ephemeris is** primarily an astronomical almanac giving, as an aid to the astronomer and navigator, the locations of celestial bodies for each day of the year. The Ephemeris can be regarded as the Greek version of the Indian Panchāngam. India is only one of seven countries that publishes an ephemeris every year. India was one of the first regions in the world to compile an ephemeris in the ancient era. The French publication *Conaissance de Temps* is the oldest of the national astronomical ephemerides, founded in 1679. The *Nautical Almanac and Astronomical Ephemeris* (usually abbreviated to the *Nautical Almanac*), an annual publication by the British Royal Observatory at Greenwich since 1767, has been a leading compilation of ephemerides since its inception. Its original purpose was to provide the astronomical information necessary to derive longitude at sea. In 1852 the U.S. Naval Observatory began publishing a book called the *American Ephemeris and Nautical Almanac,* which contained similar information to that published at Greenwich but adjusted for the meridian at Washington, D.C. Beginning with the edition for 1958, Great Britain and the United States, in a joint effort, issued ephemerides that are identical in content, although they remain separate publications with different names (the British volume was renamed *The Astronomical Ephemeris*); in 1981 the British and American publications were combined as ***The Astronomical Almanac.*** This ephemeris (adapted to the Greenwich meridian) is issued well in advance of the dates covered and contains such information as the daily right ascension and declination of the Sun, Moon, planets, and other celestial bodies, and daily data on the sunrise, sunset, Moon rise, and Moon set. Among other publications issued are *The Ephemeris* (U.S.) and *The Star Almanac for Land Surveyors* (Brit.), which are star ephemerides used by surveyors, and the *Air Almanac* (Brit./U.S.), used in air navigation. By international agreement the basic calculations of astronomical ephemerides are shared among a number of countries including France, Germany, Spain, India, Japan and Russia, but only seven countries publish an annual ephemeris of which India is one. *The Ephemerides of Minor Planets* is compiled and published annually by the Institute of Theoretical Astronomy, St. Petersburg (formerly Leningrad). In addition, the International Astronomical Union issues ephemerides for every newly discovered comet and for many newly found asteroids. Through the Minor Planet Center in Cambridge, Mass., astronomers can obtain ephemerides of any asteroid or comet.

Ephemeris Time is the actual count of Solar days from a fixed meridian.

Epicycles –**Manda paridhi** - In the Ptolemaic and Indic systems of astronomy, the epicycle (literally: on the circle in Greek) was a geometric model to explain the variations in speed and direction of the apparent motion of the Moon, Sun, and planets. It was designed by Apollonius of Perga at the end of the 3rd century BC. In particular it explained retrograde motion. Secondarily, it also explained changes in the distance of the planet from Earth.

Epistemology-(from Greek ἐπιστήμη – *epistēmē*, "knowledge, science" + λόγος, "logos") or **theory of knowledge** is the branch of philosophy concerned with the nature and scope (limitations) of knowledge it addresses the questions:

What is knowledge?

How is knowledge acquired?

How do we know what we know?

This includes logical argument or reasoning, inference, testimony, and perception. All these words have precise equivalents in Sanskrit and the word for epistemology in Sanskrit is Prāmanya.

Epoch an instant in time, such as the beginning or the middle of the year, for which positions of stars, orbital elements are given. Since the coordinates of stars are constantly changing because of precession, star positions are referred to a fundamental or standard epoch. Currently the standard epoch used by Indian calendar system is 285 CE. That is all Nirāyana longitudes and Ayanāmṡa corrections are referred to this epoch. This is also the epoch at which the start of the year coincided with the start of the Meṣa segment. But now after 1700 years this event has shifted back relative to the Gregorian calendar by 24

days. The reference date from which the ephemeris is calculated. Currently the internationally used epoch is the Gregorian calendar year of 2000. The epoch is referred to as J2000.0 is 2000 January 1.5 and also as a Julian day number JD 245 1545.0.

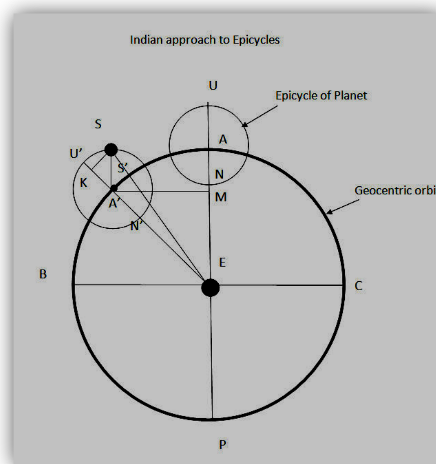
See also Ahargana, the number of days elapsed since a particular epoch date. It is a valid inference that the practice of using a reference epoch was an idea that was borrowed by the Occidentals from India, only after the prevalence and acceptance of the Hindu numerals in Europe in the 15th century and 16th century.

Prior to the widespread usage of the Hindu place value system there was no symbol for a number greater than 1000 in the Roman era.

Eponymy , the process whereby new words are formed from existing words or bases by affixation; "`singer' from `sing' or `undo' from `do' are examples of derivations", derivation of a name of a city, country, era, institution, or other place or thing from that of a person, the derivation of a general name from that of a famous person

Equation of the Center (see Chapter 1) Mandaphala, Mandoccaphala– The difference between the true and the mean anomalies (see figure 6) represented by the vectors ES, EA'.

FIGURE 6 TRUE AND MEAN ANOMALIES



Equation of Time - The Equation of Time = Apparent Time – Mean Time. Two major factors, the Obliquity of the Ecliptic (23.45 degrees) and the Earth's Orbital Eccentricity **(.0167)** are responsible for the Equation of Time, which is best illustrated by an **Analemma** or the figure eight in the heavens! The Earth moves fastest at **Perihelion** (January 3) & slowest at **Aphelion** (July 3). The amplitude of the Equation of Time is 9.87 minutes. The formula for computing the Equation of Time is,

$E = 9.87 \sin(2\theta) - 7.53 \cos(\theta) - 1.5 \sin(\theta)$ (E is in minutes)

where **$\theta = 360 (N - 81)/364$ degrees**

Equinox, vernal equinox, (Vasanth Sampat), autumnal equinox वसंत संपत - either of two points on the celestial sphere where the ecliptic and the celestial equator intersect. The vernal equinox, also known as "the first point of Aries," is the point at which the Sun appears to cross the celestial equator from south to north. This occurs about Mar. 21, marking the beginning of spring in the Northern Hemisphere. At the autumnal equinox, about Sept. 23, the Sun again appears to cross the celestial equator, this time from north to south; this marks the beginning of autumn in the Northern Hemisphere. On the date of either equinox, night and day are of equal length (12 hr each) in all parts of the world; the word equinox is often used to refer to either of these dates. The equinoxes are not fixed points on the celestial sphere but move westward along the ecliptic, passing through all the constellations of the Zodiac in 26,000 years. This motion is called the precession of the equinoxes. The vernal equinox is a reference point in the equatorial coordinate system. See also solstice, cardinal points.

Equator - See Vishuvat.

Exegesis **-** (from the Greek ἐ ξηγεῖσθαι 'to lead out') is a critical explanation or interpretation of a text.

Biblical exegesis is a critical explanation or interpretation of the Bible. The goal of Biblical exegesis is to find the meaning of the text which then leads to discovering its significance or relevance. Traditionally the term exegesis was used primarily for exegesis of the Bible. However in contemporary usage exegesis has broadened to mean a critical explanation of any text. The term is most often used for religious texts although it can be used for non-religious texts as well. The critical aspects in doing exegesis covers a wide range of disciplines. Textual criticism is the investigation into the history and origins of the text. In addition there is an examination of the historical and cultural backgrounds for the author, the text, and original audience. Then there is a classification of the types of literary genre present in the text, and an analysis of grammatical and syntactical features in the text itself. Sometimes the terms exegesis and hermeneutics have been used interchangeably. However, hermeneutics is a more widely defined discipline of interpretation theory. Hermeneutics includes the entire framework of the interpretative process, encompassing all forms of communication: written, verbal and nonverbal. Exegesis consists of interpretation principles that focus primarily on the written text.

F

Famous Phrases originating in the VEDA, A number of famous sayings originate from the verses of Dīrghatamas. **Another one bites the dust** The first time the phrase “bites the dust” appears is in the RV(1.158.4-5) where the poet Dīrghatamas has a prayer to the divine doctors and says ‘may the turning of the days not tire me, may the fires not burn me, may I not bite the earth, may the waters not swallow me’. There are disputes on what “bites the dirt” means in Sāyaṇa’s commentary in the 14th century- which means the phrase had gone out of style in India at this time as most people began to be cremated instead of buried. But we can see Dīrghatamas is using it as a prayer from death- such as don’t let me die and be burned, or die and be buried, or die and be thrown in the river. [Dust and dirt are often used interchangeably in old translations]

That said, the meaning of bites the dust would be – to die and be buried in the earth. It can also be used figuratively as something that has failed (or is in a state where it is as if it was dead and buried). Another one bites the dust is another one dead and buried- or another one finished. http://en.wikipedia.org/w/index.php?title=Dīrghatamas&action=edit

First Point of Aries the name still used for the point which is the origin of the celestial coordinate system, where the ecliptic crosses the equator, northward, and where the Sun is at the March equinox (so that it can be called the Vernal equinox point). During the Greek Era, it was on the West side of Aries, and is now in Pisces, and will in the future move into Aquarius. The opposite point in the sky is called, the first point of Libra (and is now in Virgo).



FIGURE 7
PAUL HENRI FRANCFORT

Four noble truths, आयर् सत्य) **Baudhika)** There is suffering (dukkha) in the world. Suffering arises out of desire It is possible to end suffering the way to end suffering is to adopt the eightfold path (ashtāngika marga).

Fundamentalist or Fundamentalism Fundamentalism is strict adherence to a specific set of theological doctrines typically in reaction against the theology of Modernism. The term "fundamentalism" was originally coined by its supporters to describe a specific package of theological beliefs that developed into a movement within the Protestant community of

the United States in the early part of the 20th century, and that had its roots in the Fundamentalist-Modernist Controversy of that time. The term has since been generalized to mean strong adherence to any set of beliefs in the face of criticism or unpopularity, but has by and large retained religious connotations. Historically, for some constituencies fundamentalism connotes an attachment to a set of irreducible beliefs. "Fundamentalism" is commonly used as a pejorative term, particularly when combined with other epithets (as in the phrase "right-wing fundamentalists"). In India where, the left takes a macabre pleasure in baiting the Hindu, the epithet of fundamentalist is hurled at almost all Hindus and is used indiscriminately rather than those who advocate and use violent means.

Francfort, Paul Henri, As Paul-Henri Francfort of CNRS, Paris recently observed, we now know, thanks to the field work of the Indo-French expedition that when the proto-historic people settled in this area, no large river had flowed there for a long time. The proto-historic people he refers to are the early Harappans of 3000 BCE. But satellite photos show that a great prehistoric river that was over 7 km. wide did indeed flow through the area at one time**.**

G

Garga — An ancient sage, who having propitiated Sesha, acquired from him a knowledge of the principles of astronomical science, of the planets, and of the good and evil denoted by the

Aspects of the heavens. He is one of the oldest writers on Astronomy amongst the Hindus. According to Bentley his Saṃhita dates 548 BCE, but that is merely a terminus ante quem date. The initiatory rites of Kṛṣṇa and Rāma were performed by the sage Garga, who was sent to Gokula by Vāsudeva for that purpose. In the Bhāgvata, Garga describes himself as the Purohita or family priest of the Yādavas. Garga was also the name of one of the sons of Bhavanmanyu. Garga was the son of Riṣi Bharadvaja and Susheela. He was better known as Garga Muni. He was the family priest of the family of Nanda (the foster-father of Krishna). He named Krishna as "Krishna" after receiving the name by meditation. From the Vishnu Purāṇa and other Purāṇa's, one understands that although basically of Kshatriya origin, a branch of Garga's became Brāhmaṇa and migrated westwards and joined the Yavanas (Ionians). This could be the possible reason that later day Indians referred to Greek mathematicians and astronomers as Gargāchāryas while they also maintained that a Vridha-Garga (Earlier or Older Garga) was the pioneer in astronomy.

Gargi is celebrated female sage Vachaknavi, born in the family of Garga.

Gaudapāda - Proponent of Advaita Vedanta and well versed in Buddhism. His most celebrated work is the Kārika (Gloss) on the Māndukya Upanishad.

Gavāmāyana, गवामायन walk of cows/ intercalary periods A samvatsārika sattra or yearly session of a Vedic sacrifice, lasting 361 days (12 months and 30 days); it consists of 3 sections, the first and the third taking reach 180 days and the central (Vishuvat) 1 day. The Mahāvrata sacrifice of one day is performed on the penultimate day and the order of sacrifice is reversed in the second half (Kātyāyana Srauta Sūtra). One of the purposes of the ritual was to remember the day of the year.

Gotra - A term applied to a clan, a group of families, or a lineage - exogamous and patrilineal - whose members trace their descent to a common ancestor, usually a Riṣi of the Vedic era. Atreya, Bharadvaja, Dhananjaya, Gautama, Haritasa, Kaushika, Kashyapa, Kaundinya, Kutsasa, Lomash, Mandvya, Mouna Bhargava, Mudgala Maudgalya, Moudgil, Modgil, Parasara, Sangar, Sankyanasa, Shāndilya, Somnasser, Srivatsa, Upamanyu, Vadula, Vaṡiṣṭa, Vatsa, Veetahavya, Viswāmitra, *Yāska*. Gotras — Families or tribes of Brāhmaṇas. The names of the Gotras were liable to confusion, particularly in later times, when their number had become very considerable. But the respect which the Brāhmaṇas from the very earliest time paid to their ancestors, and the strictness with which they prohibited marriages between members of the same family, lead us to suppose that the genealogical lists, even at the present day, furnish in their general outlines, a correct account of the priestly families of India. All Brahmanic families

who keep the sacred fires are supposed to descend from the seven Riṣis. These are: — Bhrigu, Angiras, Visvāmitra, Vasistha, Kasyapa, Atri, Agastya. The real ancestors, however, are eight in number: — Jamadagni, Gautama, Bharadvaja, Visvāmitra, Vaśiṣţa, Kasyapa, Atri, Agastya. The eight Gotras, which descend from these Riṣis, are again subdivided into forty-nine Gotras, and these forty-nine branch off into a still larger number of families. The names Gotra, vansa, varga, Pakṣa, and gana, are all used in the same sense, to express the larger as well as the smaller families, descended from the eight Riṣis.

$360 \div 7 = 51^{3}/_{7}$	$360 \div 12 = 30$
$364 \div 7 = 52 = 4 \times 13$	$364 \div 12 = 30^{1}/_{3}$
$365 \div 7 = 52^{1}/_{7}$	$365 \div 12 = 30^{5}/_{12}$
$366 \div 7 = 52^{2}/_{7}$	$366 \div 12 = 30^{1}/_{2}$

A Brāhmaṇa, who keeps the sacrificial fire, is obliged by law to know to which of the forty-nine Gotras his own family belongs, and in consecrating his own fire he must invoke the ancestors who founded the Gotra to which he belongs. Each of the forty-nine Gotras claims one, or two, or three, or five ancestors, and the names of these ancestors constitute the distinctive character of each Gotra. Max Müller A. S. L., p. 80.

Graha Brāhmaṇa Vṛtta – center of the orbital circle of the Planet, center of the epicycle

Greenwich Sidereal Time (GT) = 0.0 hours UT

Gregorian Calendar Reform

When Julius Caesar took power in Rome, the Roman calendar had ceased to reflect the year accurately. The provision of adding an intercalary month to the year when needed had not been applied consistently, because it affected the length of terms of office.

FIGURE 8 POPE GREGORY XIII.



The Julian reform lengthened the months (except February, owing to its religious significance) and provided for an intercalary day to be added every four years to February, creating a leap year.

This produced a noticeably more accurate calendar, but it was based on the calculation of a year has 365 days and 6 hours (**365.25^{d}**). In fact, the year is 11 minutes and 14 seconds less than that. This had the effect of adding three-quarters of an hour to a year, and the effect accumulated. By the sixteenth century, the vernal equinox fell on March 10.

Pope Gregory XIII dedicated his papacy to implementing the recommendations of the Council of Trent. By the time he reformed the Julian calendar in 1582 (using the observations of Christopher Clavius and Johannes Kepler), it had drifted 10 days off course. To this day, most of the world uses his Gregorian calendar.

Under Pope Gregory XIII the leap rule was altered: century years, which are divisible by four, would not be leap years unless they are also divisible by 400. This makes the mean year 365.2425 days (365 d, 5 h, 49 min, 12 s) long. While this does not synchronize the years entirely, it would require 35 centuries to accumulate a day. This new calendar was synchronized with the traditional seasons again and was not applied to dates in the past, which caused a leap of at least ten days from the final day the Julian calendar was in effect. Thus the day after October 4 1582 was named October 15, 1582 and the 11 days in between are completely missing. This reform slowly spread through the nations that used the Julian calendar, although the Russian church year still uses the Julian calendar. The times varied so widely that some countries had to drop more than ten days: Great Britain, for instance, dropped eleven because the

new Gregorian calendar was adopted only in 1752. England finally followed suit in 1752, declaring that Wednesday, September 2, 1752 was immediately followed by Thursday, September 14, 1752 as shown in the below calendar. The English calendar was also used in America.

English Calendar:
September 1752

Su	M	Tu	W
	Th	F	Sa
&;	&;	1	2
	14	15	16
17	18	19	20
	21	22	23
24	25	26	27
	28	29	30



FIGURE 9 THE GREGORIAN CALENDAR COMMISSION, 1581



Sweden followed England's lead in 1753. Russia, however, did not follow suit until 1918, when January 31, 1918 was immediately followed by February 14th. In fact, Russia is not on the Gregorian calendar, but on a more accurate one of their own which they developed. The Russian calendar is designed to more closely approximate the true length of the tropical year, thus has one additional rule for when a year is a leap year. It will remain in synchronization with the Gregorian calendar for thousands more years, by which time one or both will have probably fallen into disuse. Similarly, the Iranian calendar is also a more accurate version of the Gregorian calendar (Ross).

TABLE 1 REFORMERS CITE SEVERAL PROBLEMS WITH THE GREGORIAN CALENDAR
1. It is not perpetual. Each year starts on a different day of the week and calendars expire every year.
2. It is difficult to determine the weekday of any given day of the year or month.
3. Months are not equal in length nor regularly distributed across the year, requiring mnemonics (e.g. "Thirty days hath September…") to remember which month is 28, 29, 30 or 31 days long.
4. The year's four quarters (of three full months each) are not equal. Business quarters that are equal would make accounting easier.
5. Its epoch (origin) is not religiously neutral. The same applies to month and weekday names in many languages.
6. Each month has no connection with the Lunar phases.
7. It is impossible to solve all these issues in just one calendar.

Most plans evolve around the Solar year of little more than 365 days. This number does not divide well by seven or twelve, which are the traditional numbers of days per week and months per year respectively. The nearby numbers 360, 364, and 366 are divisible in better ways. There are also Lunar centric proposals.

Grihastya - The second stage of the Varna Ashrama system, namely that of a householder or married man or woman.

Guṇa - There are 3 Guṇa's, Sattva, Rajas, and Tamas and these three Guṇa's occur in each and every individual in varying degrees. The relative proportion of each in the total determines the essential nature of the individual. It follows that at any given time an individual, may exhibit different modes of behavior as his personality matures and develops. The son of a Brāhmaṇa may choose not to follow the priestly vocation and may elect to go into law. As a general rule of thumb one elects to be in a profession which utilizes his Guṇa fully. For example Brāhmaṇas tend to cluster around intellectual pursuits (teaching, legal, corporate management, administration etc. In the past the choice of professions available to Brāhmaṇas were limited to priestly duties and the services he could render as a Minister to the Mahāraja including mundane tasks such as accounting and cooking. In recent years substantial numbers of Brāhmaṇas faced with increasing discrimination from their own government have elected to go into Business, so that his Varna is that of a Vaisya, unless he maintains his competency and knowledge of the Vedic scripture and adheres to the injunctions of a Brāhma105a. Most Indian philosophers accept the view of the Saṇkhya philosophy when it refers to the definition of the Guṇa and their relationship to Prakrti and Puruṣa.

Guṇa Varna Vyavastha - The Varna system, namely Guṇa Varna Vyavastha that produced the Varnāshrama Dharma was the world's early attempt at a meritocracy. That the system was eminently successful in its own way , I have no doubt because the resulting civilization flourished for well over 5 millennia, until its very foundations were attacked by barbarians from both within and without; by barbarians, whose notion of entertainment was to build a pyramid of skulls, in order to terrorize the local population to capitulate. The current system in place after the colonial power was done reinventing and reshaping it to its own specifications, and which goes by the name Caste, is so utterly different in all significant ways, that we can safely say it has little to do with the Hindu faith or Hindu traditions such as the Guṇa Varna Vyavastha. The vedic division of people into 4 Varnas (Brāhmaṇa, Rājanya, Vaisya, and Shudra) is by Guṇa and Guṇa only and is known as the Guṇa Varna Vyavastha. The Asrama system refers to the four stages of one's life, namely Brahmachārya (life of an unmarried student), Grihastya (life of a householder), Vānaprasthaya (life of a retired householder), sanyāsa (life of a monk)

H

Hermeneutics - Hermeneutics is the study of interpretation theory, and can be either the art of interpretation, or the theory and practice of interpretation. **Traditional hermeneutics** — which includes **Biblical hermeneutics** — refers to the study of the interpretation of written texts, especially texts in the areas of literature, religion, and law. Contemporary, or **modern**, hermeneutics encompasses not only issues involving the written text, but everything in the interpretative process. This includes verbal and nonverbal forms of communication as well as prior aspects that affect communication, such as presuppositions, pre-understandings, the meaning, and philosophy of language, and semiotics. **Philosophical hermeneutics** refers primarily to Hans-Georg Gadamer's theory of knowledge as developed in *Truth and Method*, and sometimes to Paul Ricoeur. **Hermeneutic consistency** refers to analysis of texts for coherent explanation. A **hermeneutic** (singular) refers to one particular method or strand of interpretation.

Hinduism - Also known as Sanatana Dharma, the eternal faith; there are roughly 900 million Hindus in the world as of 2008 (see Dharma).

Human evolution

This cranium, of *Homo heidelbergensis*, a Lower Paleolithic predecessor to *Homo neanderthalensis* and possibly *Homo sapiens*, dates to sometime between 500,000 to 400,000 BC. Human evolution is the part of biological evolution concerning the emergence of humans as a distinct species. It is the subject of a broad scientific inquiry that seeks to understand and describe how this change and development occurred. The study of human evolution encompasses many scientific disciplines, most notably physical anthropology, paleoanthropology, paleontology, archeology, linguistics, and genetics. The term *human*, in the context of human evolution, refers to the genus *Homo*, but studies of human evolution usually include other hominids, such as the australopithecines.

I

Ice Age, the last peak of the Ice age occurred 20,000 years ago. See for instance[292] . Periodic and cyclical changes in the rotation and orbit of the Earth that Milutin Milankovich, a Serbian mathematician and physicist, correlated to climatic effects. These cycles influence the amount of solar radiation striking different parts of the Earth at different times of the year, and cause the advance and retreat of the polar ice caps. There are three cycles:

Changes in the Eccentricity of the Earth's orbit, altering the distance between Earth and the Sun at aphelion and perihelion, with a period of about 100000 years.

Variations in the tilt of the Earth's rotational axis (obliquity of the ecliptic), with a period of 42000 years.

A movement (wobble) in the angle by which the axis of the Earth's rotation is tilted in respect of the orbital plane, altering the seasons at which aphelion and perihelion occur (precession of the equinoxes), with a period of about 21000 years.

Indo-Āryan languages - A family of languages spoken over a large area of the Eurasian land mass; see Indo-European Languages

Indo-European languages - A family of languages spoken over a vast geographical area from India to most parts of Europe.

Indo-Iranian languages - the Indo Iranian branch of the Indo European language family, spoken in central Asia, Iran and the Indian subcontinent

Indology - Indology is a name given by Indologists to the academic study of the history, languages, and cultures of the Indian subcontinent. Strictly speaking it encompasses the study of the languages, scripts of all of Asia that was influenced by Indic culture It may be surprising to learn that the first pioneer in Indology was the 12th Century Pope, Honorius IV. The Holy Father encouraged the learning of oriental languages in order to preach Christianity amongst the pagans. Soon after this in 1312, the Ecumenical Council of the Vatican decided that-“The Holy Church should have an abundant number of Catholics well versed in the languages, especially in those of the infidels, so as to be able to instruct them in the sacred doctrine.” The result of this was the creation of the chairs of Hebrew, Arabic, and Chaldean at the Universities of Bologna, Oxford, Paris, and Salamanca. A century later in 1434, the General Council of Basel returned to this theme and decreed that –“All Bishops must sometimes each year send men well-grounded in the divine word to those parts where Jews and other infidels live, to preach and explain the truth of the Catholic faith in such a way that the infidels who hear them may come to recognize their errors. Let them compel them to hear their preaching.” Centuries later in 1870, during the First Vatican Council, Hinduism was condemned in the “five anathemas against pantheism” according to the Jesuit priest John Hardon in the Church-authorized book, The Catholic Catechism. However, interests in Indology only took shape and concrete direction after the British came to India, with the advent of the

[292] *Imbrie, J. and K.P.Imbrie, Ice Ages: Solving the Mystery (Short Hills NJ: Enslow Publishers) 1979*

discovery of Sanskrit by Sir William Jones in the 1770's. Other names for Indology are Indic studies or Indian studies or South Asian studies. Political motivations have been always dominant in the pursuit of Indological studies right from the outset since the time of Sir William Jones, when he discovered the existence of Sanskrit. In fact the British presence in India was steadily increasing long before the Battle of Plassey in 1757 CE, but so great was the insularity of the colonial power that it took almost three hundred years for a scholar like Sir William to show up in India after Vasco Da Gama landed of the cost of Goa in 1492 CE, and notice the similarities between Sanskrit and the European languages. It is one of the supreme ironies of History that the discovery of Sanskrit and the initiation of the study of Indology may yet prove to be the kiss of death for the study of the Indic traditions and it appears likely that Macaulay may yet be proven right in his prognostications about the future of the Indic languages and traditions of India.

Indus script - While several decipherments have been proposed including the recent work by Rajaram and Jha[131], it is possible the problem may never achieve a solution satisfactory to both the Indics and the Western Indologists. Most Indics believe that this was the forerunner of the Brahmi script. The Brahmi script is the progenitor of almost all of the languages and scripts of India and most of the rest of South East Asia .The Brahmi script has all of the phonetic characteristics to be found in all the successor scripts of Asia. To suggest a Semitic origin for a Brahmi script, as Buhler[293] and other Occidental Indologists have done, is highly problematical since Semitic scripts (including all the Roman scripts of Europe) do not have the characteristic Vowel strokes that Brahmi scripts have whenever a vowel is appended to a consonant such as in आचार्य (the long 'a' vowel is represented by a vertical stroke). The name Brahmi suggests that the script was developed along the banks of the Sarasvati River, since Brahmi is synonymous with Sarasvati[294]

Indus Valley Civilization or Harappan Civilization - AKA Sarasvati Sindhu Civilization (SSC), the civilization that endured for several millennia in the Sarasvati and Sindhu (Indus) river valleys was in reality spread over a very large area stretching to Asmāka region presumed to be the upper Godavari region in the South. The people who inhabited these valleys are also referred to as the Vedic Harappans by Bhagwan Singh. Most of the recent excavations indicate a heavy preponderance of settlements, about 400 in number on the banks of the dried up Sarasvati river. Mohenjo Daro and Harappa represent a late phase of the civilization. European Indologists go to extraordinary lengths to make a distinction between the Vedic civilization and the SSC despite the fact they are located spatially and temporally in the same place and time. That they got away with this subterfuge for such a long time (it is still the official version of History in Indian text books) is a tribute to the farsightedness and tenacity of successive British administrators and scholars who always put British national interest before every other criterion including the truth. Their reasons for engaging in such intellectual dishonesty are chronicled in The South Asia File.[132]

Inference – Anumāna -A process of reasoning that moves from premises to conclusion; the principal types of inference are deduction and induction. Distinguishing between good and bad inferences is the aim of logic

Intercalate: to insert an interval of time (e.g., a *day* or a *month*) within a *calendar*, usually so that it is synchronized with some natural phenomenon such as the seasons or lunar *phases*.

Interior or Inferior Planets – refer to Mercury and Venus. It is generally easier to predict accurate longitude of Venus, since its orbit is very close to a circle, while Mercury is far more elliptical. Most approximations are power series in e, the Eccentricity , and hence it converges faster to the true value.

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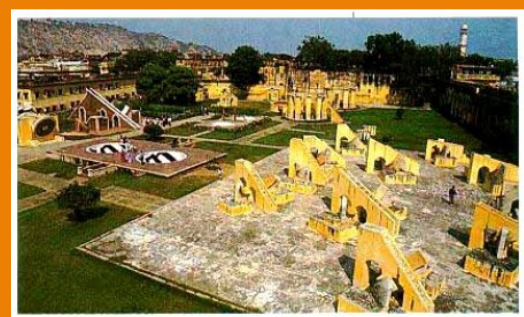
[293] Bühler George, 1904, Indian Paleography (Translated by John Faithful Fleet), The Indian Antiquary 33, Appendix: page 1102. Bühler, George, On the origin of the Brahmi alphabet,. - 3rd ed., Vāranasi, 1963, xvi, 240 p.

[294] Rajaram, N . S., and N Jha, "The deciphered Indus script" .Āditya Prakāshan, Delhi , 2005, ISBN 8177420151

In going from Superior to Inferior, deferents and epicycles essentially swap roles. It is the deferents of the inferior planets, rather than the epicycles themselves, which represent the earth's orbit. Ptolemy makes the error of neglecting the non –uniform rotation of the planets around the epicycles instead of neglecting the non uniform rotation of the epicycle centers around the deferents. By observing the path of Venus relative to the sun, Nīlakaṇṭa (Tantrasańgraha, 1500 CE) was able to deduce that the inferior planets were essentially revolving around the Sun. Literally means lower, as the Latin word means, in the gravitational field of the Sun; which therefore have two kinds of conjunction (inferior and superior), never have oppositions, but instead are seen near their greatest elongations. Recently asteroids have been seen, which must also count as inferior planets, since their average distance from the sun are less than that of the Earth.



Iranian peoples - The ancient Iranians or Avestan, the people who composed the Avesta, have much in common with the Vedics. In fact it is believed by some that the Iranians are descended from the Druhyus. The language of the Avesta is easily discernible to those familiar with Sanskrit and the names of Persian Kings (the original names not the Greek version we learned in English history books). For instance the Sanskrit or Iranian version of Darius is Druhyu. It is surmised that a branch of the Bhrigu Riṣi family, that composed the Atharvan Veda eventually composed the Avesta and that Zarathustra (Zoroaster) the founder of the Parsee religion, was a Bhrigu.



Irrational Numbers – The notion that certain fractions give rise to decimal numbers that do not have a recognizable pattern of numbers that repeats itself was recognized by the Indic ancient at a very early stage in their development of mathematics and in fact Āryabhaţa alludes to the irrationality of PI in the following passage where he uses the term 'asanna'. Āryabhaţa worked n the approximation for Pi (π), and may have come to the conclusion that π is irrational.

In the second part of the Āryabhaţīya (Gaṇitapāda 10), he writes:

चतुराधकं शतमष्टगुणं द्वाषष्टिस्ता सहस्राणाम् ।

अयुतद्वयविष्कम्भस्यासन्नोवृत्तपरिणाहः ।। 10

Chaturādhikam Śatamaśţaguṇam Dvāśaśţistathā sahasrāṇām Ayutadvayaviṣkambhasyāsanno vrîttapariṇahaḥ.

"Add four to 100, multiply by eight, and then add 62,000. By this rule the circumference of a circle with a diameter of 20,000 can be approached". This implies that the ratio of the circumference to the diameter is ((4+100) ×8+62000)/20000 = 3.1416, which is accurate to five *significant figures*.

FIGURE 10, 11 JANTAR MANTAR BY SAWAI JAI SINGH

It is speculated that Āryabhaţa used the word āsanna (approaching), to mean that not only is this an approximation but that the value is incommensurable (or *irrational*). If this is correct, it is quite a sophisticated insight, (because the irrationality of pi was proved in Europe only in 1761 by *Lambert*)."

J

Jantar Mantar A series of astronomical observatories built by Mahāraja Jai Singh of Jaipur, the best known of which is the one in Delhi. See for instance, http://www.crystalinks.com/indiastronomy.html

Jnana Yoga ज्नान the path of knowledge Jñāna (also spelled "Gyāna"; Devanagari घ्यान (is the Sanskrit term for knowledge. In Hinduism it means true knowledge, Parā Vidya, the knowledge that one's self atman is Ultimate Reality Brahman. In Buddhism, it refers to pure awareness that is free of conceptual encumbrances, and is contrasted with Vijnana, which is a moment of 'divided knowing'. Jnana yoga is one path (marga) towards moksha (liberation), while Yoga offers different paths for different temperaments such as Bhakti and Karma Yoga.

Jivanmukta - Adi Sankara gives the true definition of a Jivanmukta - The great souls he says , calm and tranquil, live, regenerating the world like the spring; and themselves having crossed the ocean of embodied existence, and death, help those who struggle, for the same end, without the least trace of personal motives or advantage.

Jya, Jiva ज्य The Sanskrit word for R * Sine of an angle- see also Kotijya, Jyotpatti Gaṇita, trikonamiti, Utkramjya.

Jyeṣṭhadeva (1500-1575) pupil of Damodara, son of Parameṣvara of Vataserri, of Parannottu family one of the famed band of Kerala astronomers who graced the country for over 3 centuries. He is most known for authoring a commentary *Gaṇita Yuktibhāṣā*[295], the first calculus text of the world. This work was unique at the time for its exacting proofs of the theorems it presented. He also authored the *Drk-karana* on astronomical observations.

Julian Day Count: The Julian Day Count is a uniform count of days from a remote epoch in the past (-4712 January 1, 12 hours Greenwich Mean Time (Julian proleptic Calendar) = 4713 BCE January 1, 12 hours GMT (Julian proleptic Calendar) = 4714 BCE November 24, 12 hours GMT (Gregorian proleptic Calendar)). At this instant, the Julian Day Number is 0. It is convenient for astronomers to use since it is not necessary to worry about odd numbers of days in a month, leap years, etc. Once you have the Julian Day Number of a particular date in history, it is easy to calculate time elapsed between it and any other Julian Day Number.

The Julian Day Count has nothing to do with the Julian calendar introduced by Julius Caesar. It is named for Julius Scaliger, the father of Josephus Justus Scaliger, who invented the concept. It can also be thought of as a logical follow-on to the old Egyptian civil calendar, which also used years of constant lengths. In fact the circumstantial evidence points to the adoption of this number by the Occident after the Principal of the Collegio Romano sent a posse of 60 to 70 Jesuits to Malabar in 1560 CE. It was shortly after this that the reform of the Julian calendar was instituted by the Vatican and the Julian Day number appears to be a natural outcome of the knowledge gained by the Jesuits and is in fact a direct adaptation of the Ahargana system in use in India for a number of centuries. It is also pertinent to point out that the Greeks did not have the mathematical savvy to do the algorithmic calculations necessary to arrive at these numbers and infact had neither a name nor a symbol for a number greater than 1000. Scaliger chose the particular date in the remote past because it was before recorded history and because in that year, three important cycles coincided with their first year of the cycle: The 19-year

[295] *Gaṇita-Yuktibhāşā by Jyeşţhadeva, Malayalam text critically edited by KV Sarma. Explanatory notes by K Ramasubramanian, MD Srinivas, MS Sriram, Published by Hindustan Book agency, 2008*

Metonic Cycle, the 15-year Induction Cycle (a Roman Taxation Cycle) and the 28-year Solar Cycle (the length of time for the old Julian Calendar to repeat exactly).
It is easy (with your calculator) to calculate the Julian Day Number of any date given on the Gregorian calendar. The Julian Day Number so calculated will be for 0 hours, GMT, on that date. Here's how to do it:

1) Express the date as **Y M D**, where Y is the year, M is the month number (Jan = 1, Feb = 2, etc.), and D is the day in the month.
2) If the month is January or February, subtract 1 from the year to get a new Y, and add 12 to the month to get a new M. (Thus, we are thinking of January and February as being the 13th and 14th month of the previous year).
3) Dropping the fractional part of all results of *all multiplications and divisions*, let

A = Y/100
B = A/4
C = 2-A+B
E = 365.25x (Y+4716)
F = 30.6001x (M+1)
JD= C+D+E+F-1524.5

This is the Julian Day Number for the beginning of the date in question at 0 hours, Greenwich Time. Note that this always gives you a half day extra. That is because the Julian Day begins at *noon*, Greenwich Time. This is convenient for astronomers (who until recently only observed at night), but it is confusing.
Example: If the date is 1582 October 15,
Y = 1582
M = 10
D = 15
A = 15
B = 3
C = -10
E = 2300344
F = 336
JD = 2299160.5

To convert a Julian Day Number to a Gregorian date, assume that it is for 0 hours, Greenwich Time (so that it ends in 0.5). Do the following calculations, again dropping the fractional part of all multiplications and divisions. *Note: This method will not give dates accurately on the Gregorian Proleptic Calendar, i.e., the calendar you get by extending the Gregorian calendar backwards to years earlier than 1582. Using the Gregorian leap year rules.* ***In*** *particular, the method fails if Y<400.*
Z = JD+0.5
W = (Z - 1867216.25)/36524.25
X = W/4
A = Z+1+W-X
B = A+1524
C = (B-122.1)/365.25
D = 365.25xC
E = (B-D)/30.6001

F = 30.6001xE
Day of month = B-D-F
Month = E-1 or E-13 (must get number less than or equal to 12)
Year = C-4715 (if Month is January or February) or C-4716 (otherwise)
Example: Check the first calculation by starting with JD = 2299160.5
Z = 2299161
W = 11
X = 2
A = 2299171
B = 2300695
C = 6298
D = 2300344
E = 11
F = 336
Day of Month = 15
Month = 10
Year = 1582

Remark: One can calculate the Julian Calendar Date-->Julian Day Number or vice versa by ignoring the calculation of A and B, and setting C=0; to go from Julian Day Number to Julian Calendar Date, bypass the calculation of W and X and simply set A=Z. These calculations are useful also when converting between the Gregorian and Julian calendars (e.g., to correlate dates on the Julian calendar in England prior to 1752 with dates on the Gregorian calendar). For example, to go from Gregorian to Julian calendar date, convert the Gregorian date to Julian Day Number, then convert the Julian Day Number to Julian calendar date. This method even works for dates prior to 1582 and correctly gives years prior to the Common Era as negative years (with year 0 corresponding to 1 BCE, year -1 corresponding to 2 BCE, etc.) However, it does *not* work with negative Julian Day Numbers and does *not* work when going *to* the Gregorian calendar for years before 400 CE.

Jyotiṣa, (aka Nakṣatra Kalpa, Nakṣatra Sastra, Nakṣatra Gaṇita, Nakṣatra Vidya) - one of the 6 Vedāṅgas, also known as the science of light. It includes the study of the motion of Celestial Objects or Astronomy and the effects of the forces arising from these bodies and their effects on the human mind. It is the hypothesis of Vedic Astrology that such effects can be predicted by studying the relative location of the planets and the stars. Jyotiṣa is often discussed as the instructional element of the RV, and as such is a Vedāṅgas, or "body part" of the Vedas. Jyotiṣa is called the Eye of the Veda, for its believed ability to view both phenomenal reality and wisdom itself. Part of a larger Vedic curriculum including mathematics, architecture, medical and military applications. The author of this Vedāṅga is purported to be one **Lagadha.**

Jyeṣţhadeva (1500 -1575) wrote the following

1. Yuktibhāṣā : CESS 3.76-77
2. Drk-karana

K

Kakṣyāmaṇḓala – circumference of deferent circle = 2πR
Kakṣyāvṛtta - , a circle with center at the Earth s center, and Trijya as Radius (note that trijya = 1 radian)
Kakṣyākarṇa – the radius of the orbit
Kala – an arc minute, 1/60th of a degree
Kalamsa – degree of time

Kālidāsa, कालिदास The poet laureate of ancient India. The author of the most widely known text and play Shakuntala
Kalpa – a day of Brahma, 4.32 $*10^9$ years, Aeon, generally a very large number.
Kalpa Sūtras - constitutes part of the Vedāńga consists of Grihya Sūtras, Dharma Sūtras, Sulva Sūtras, Srauta Sūtras.

Kāma, काम Pleasure, desire, wish, love; enjoyment. Earthly love, aesthetic and cultural fulfillment, pleasures of the world (often used in the sense of sexual desire, but not necessarily so), the joys of family, intellectual satisfaction. Enjoyment of happiness, security, creativity, usefulness, and inspiration. An essential ingredient for the emotional health of an individual and recognized as such by the ancient Vedics. Kama is one of the four Purushārthas or goals of life, the others being dharma, artha and moksha.

Kārika कारिक- Gloss or explanatory text of an original text, such as the Kārika of the Māndukya Upanishad by Gaudapāda, or the commentary on Āryabhaṭīya by numerous commentators.

Karma Yoga – कर्म योग Karma-yoga, or the "discipline of action" is based on the teachings of the Bhagavad Gita, a holy scripture of Hinduism. One of the four pillars of yoga, Karma yoga focuses on the adherence to duty (dharma) while remaining detached from the reward. It states that one can attain Moksha (salvation) by doing ones duties in an unselfish manner. A great portion of the Bhagavad Gita is engaged in discussing the efficacy of various Yogas towards the goal of self realization or Moksha. Initially Arjuna is bewildered, when Bhagavan says that the Yoga of Knowledge is superior to the Yoga of action, even though desire less it may be. Why then do you ask me to fight asks an exasperated Arjuna of his friend and mentor, if such be the case. The answer by Bhagavan and elucidated by Adi Sankara in his Bhāṣya is one of the major insights of this lovely Celestial song. As explained by Adi Sankara, Karma Yoga consists of 4 principles 1. Giving up an egoistic attitude (BG 18-46), 2. Giving up the hankering for the fruits or results of one's action (BG 2-39), 3. Maintaining equanimity in the face of desirable and happy circumstances as well as undesirable and not so pleasant situations (BG 2-48) 4. Surrendering of all actions as an offering to the Lord (Iswara) wholeheartedly (BG 3-33). It is possible to transcend Karma Yoga by the Yoga of Knowledge, which is in fact the superior approach, but such an alternative is not for every individual, and is best suited for those who have realized Brahman.
Khagola - Celestial sphere or armillary sphere, a term used for both the geometrical celestial sphere as well as the astronomical instrument called the armillary sphere.
Khagola-Śāstra. – The science of Astronomy – the science of the celestial sphere
Koti - perpendicular
Kotijya कोटिज्य Cosine θ, also **Kojya**
Krānti - Declination
Kumbha – Aquarius the water carrier
Kshatriya, क्षत्रिय the Varna identified in the classical Indic tradition as those entitled to exercise military power and perform sacrifices, the dominant Guṇa in the Kshatriya Varna is one of Rajas, and a passion for action. It is your Dharma to engage in action protects the aged and infirm and the children and women in your protection. It is better to follow one's own Dharma (dictated by ones Guṇa's) admonished Sri Kṛṣṇa to Arjuna than to try something, however beguiling, which is not so suited.
Kurgan - a region in Europe from where the putative emigration of the mythical *Aryan* race took place
Kurma: Cassiopeia (?)

L
Lagadha - The earliest astronomical text—named Vedānga Jyotiṣa—dates back to around 1400 -1200

BCE, and details several astronomical attributes generally applied for timing social and religious events.[10] The Vedānga Jyotiṣa also details astronomical calculations, calendrical studies, and establishes rules for empirical observation.[10] Since the texts written between 1800 BCE and 1200 BCE were largely religious compositions the *Vedānga Jyotiṣa* details several important aspects of the time and seasons, including Lunar months, Solar months, and their adjustment by a Lunar leap month of *Adhimāsa*.[11] *Ritu* and xpands the Intellect of Students), which corrects several assumptions of Āryabhaţa.[15] The *Śiṣyadhīvrddhida* of Lalla itself is divided into two parts: *Grahādhyāya* and*Golādhyāya*.[15] *Grahādhyāya* (Chapter I-XIII) deals with planetary calculations, determination of the mean and true planets, three problems pertaining to diurnal motion of Earth, eclipses, rising and setting of the planets, the various cusps of the Moon, planetary and astral conjunctions, and complementary situations of the Sun and the Moon .[15] The second part—titled *Golādhyāya* (chapter XIV–XXII)—deals with graphical representation of planetary motion, astronomical instruments, spherics, and emphasizes on corrections and rejection of flawed principles.[15] Lalla shows influence of Āryabhaţa, Brahmagupta, and Bhāskara I.[15] His works were followed by later astronomer's Śrīpati, Vateśvara, and Bhāskara II.[15] Lalla also authored the *Siddhāntatilaka*.[15]

Lambajya is a term used to denote the Kotijya of the latitude or the sine (Jya) of the co-latitude

Longitude, angular distance around an axis of rotation or revolution. Specifically there is terrestrial longitude; right ascension, which is really what, corresponds to it in the sky; ecliptic longitude, which is usually what longitude by itself means in astronomy; galactic longitude; azimuth around the horizon; the longitude of planets around their own orbits etc.

Lunation a cycle from new moon to new moon, about 29.53 days, the actual number varying from 29.27 to 29.83.

M

Mādhavācharya - Celebrated religious teacher and scholar of the 14th century, one of the main teachers of the Dvaita-Vedanta school of pronounced dualism. It teaches the existence or permanent reality of two fundamental principles in universal nature: spirit and matter, or divinity and the universe. This dualism is in direct contrast with the unity doctrine taught in the Advaita-Vedanta or non-dualistic system of Sankarācharya.

Madhya Gati – mean motion of the planet

Madhyama Graha – mean longitude and latitude of object, mean planet λ_m

Madhyama Mandakendra – mean anomaly λ_m

Mahāvrata - winter solstice

Mahāvākya, महावाक्य

The 4 expressions that embody Vedanta, the essence of attaining Jivanmukta.

The Mahāvākyas are the four "Great Sayings" of the Upanishads, foundational religious texts of Hinduism.

These four sayings encapsulate the central Truth of Hinduism.

The Mahāvākya are:

1) *Prajnānam Brahman* "Consciousness is Brahman" (Aitareya Upanishad 3.3).

2) *Ayam Ātma Brahman* "This Self (Atman) is Brahman" (Mandukya Upanishad 1.2)

3) *Tat Tvam Asi* - "That Thou art" (Chandogya Upanishad 6.8.7)

4) *Aham Brahmāsmi* - "I am Brahman" (Bṛhadāranyaka Upanishad 1.4.10)

All four of these, in one way or another, indicate the unity of the individual human being with Brahman. Brahman is Absolute Reality, Cosmic Consciousness, the fundamental primordial essence from which all divinities and all worlds arise and the Dharma asserts that each human being, in her or his innermost self, is this ultimate transcendent God-Reality. It is through practices like yoga, and meditation that the

individual can realize her or his unity with the Divine and escape bonds of this world. The most forthright statement of the above proposition is to be found in texts propounding Advaita Vedanta. The Bhagavad Gita is one of the texts that enumerate the various paths one may take to attain Jivanmukta.

Mananam - part of the process of gathering of knowledge using techniques such as sravaṇam, mananam, and nididhyasanam. Mananam means to ponder over the material that one has read or heard.

Manda slow, motion**,** refers generally to the correction of the planet sun combination, which forms the deferent. It is the correction needed to obtain the equation of the center.

Manda Kendra Mean Anomaly to calculate the equation of the center.

Mandakendrajya – R sin λ_m

Manda-kaksya-mandala the manda orbits in which they move

Mandaprattivṛtta, **मंद** ंर्रतिव्रत्त , the deferent

Manda Samskāra – correction applied to mean planet (using epicycle) – manda correction for obtaining the equation of the center.

Manda Sphuta Graha – the manda corrected longitude. For the exterior planets, the Manda Sphuta Graha is the same as the true heliocentric longitude. For the exterior planets, Mars, Jupiter and Saturn, the Manda Samskāra is equivalent to taking into account the Eccentricity of the planets orbit around the Sun. Different computational schemes are discussed in Indian astronomical literature. However, the manda correction in all of these schemes coincides to the first order of magnitude in Eccentricity, with the equation of the centre in modern astronomy.

Mandocca Apogee **–**actual meaning - apex of slowest motion, where the angular velocity of the Planet or orbiting body attains its minimum value. See also **Śīghroccha**

Mandocca nīcha vṛtta or **Manda nīcha vṛtta** – epicycle of the exterior planet (also called manda circle).

Mean Motion The average angular velocity of an orbiting body during its revolutions around the earth. In the case of the heliocentric system the mean motion is the actual value at the 2 nodes (the equinoctial points).

Meṣa - Aries, **Meṣādi –** first point of Aries

Metonic cycle (see also Adhikamāsa) - a cycle whereby every three years a Lunar month is added to bring the Lunar cycle in synchronization with the Solar cycle. It turns out that it takes nineteen years to bring the two cycles in synchronization, so that a new Moon occurs exactly on the same Solar day that it did 19 years ago. When combined with the 4 year cycle used in the Julian calendar, yields a total cyclic time of 7*4*19 = 532 years. This is the time in years that has to elapse in order for the same weekday to occur on the same date, for every month of the year. It is attributed to Meton, the Greek astronomer and now is credited to Babylonian astronomers, in the 5^{th} century BCE, but should properly be credited to YĀJNAVALKYA in the Śatapatha Brāhmaṇa, who first postulated the 95 year old synchronization cycle. The higher number was necessitated by the greater accuracy of the observations and the greater accuracy that the Ancient Indics demanded in the final result. The result was that the Sun and the Moon were synchronized to within.

Mina - Pisces

Mitanni - in 1400 BCE when the Hittite and the Mitanni (2 neighboring kingdoms in Anatolia, present day Turkey signed a treaty they invoked the blessings of their Gods). The invocation is addressed to the Nasatyas, Mitra, and Varuna, Hindu Vedic deities from a distant past. This implies either of 2 possibilities. That the people who worshipped these deities subsequently travelled to India or that they emigrated out of India about the time the Sarasvati dried up. We believe the second possibility is the more logical one and makes chronological sense.

Mithuna - Gemini

Moksha -"Liberation." Is synonymous with Freedom from rebirth through the ultimate attainment, realization of the Self God, Para-Siva. The spiritual attainments and super conscious joys, attending

renunciation and yoga leading to Self Realization. Moksha comes through the fulfillment of dharma, artha, and Kāma (known in Tamil as Aram, porul, and inbam, and explained by Tiruvalluvar in Tirukural) in the current or past lives, so that one is no longer attached to worldly joys or sorrows. It is the supreme goal of life, called paramartha. This is a distinction between the Dhārmik traditions originating in the Indian subcontinent from the very earliest time periods in history and other religious belief systems. The propensity to cater to the higher needs (in the Maslow hierarchy) from the very inception of the tradition is a uniquely Indic development. Merely to emphasize this as a spiritual characteristic is to minimize the pragmatic and psychological needs of the human species. Paying special attention to the fulfillment of these needs is a distinctive characteristic of Indic dharma.

Mrga: Orion (AB)

Mrgavyadha: Sirius (AB)

Mumukṣutva - An intense thirst for Brahma Vidya or higher knowledge (Parā Vidya)

N

Nakṣatras - The concept of positing 27 Nakṣatras in the sidereal Zodiac goes back to antiquity at least in India. The ancients divided the sky in 27 or 28 Lunar mansions or Nakṣatras, characterized by asterisms (apparent groups of stars), one for each day that the Moon follows its track among the stars.

Nakṣatra dina or Nakṣatra divas– see also sidereal day. The sidereal day is measured with respect to the distant stars. A mean sidereal day is about 23h 56m in length. Due to variations in the rotation rate of the Earth, however, the rate of an ideal sidereal clock deviates from any simple multiple of a unit of time.

Nakṣatra -vidya - The astronomical aspect of Jyotiṣa (which sometimes includes Astrology)

Navaratna of Vikramāditya

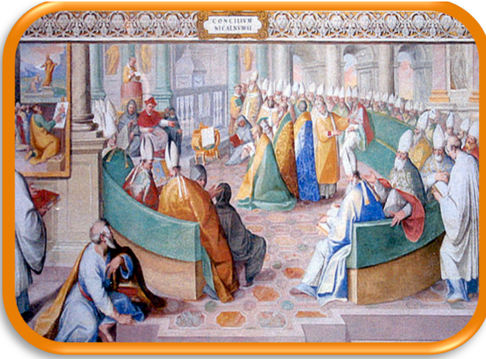
The names of the nine gems are found in the following Sanskrit verse:

dhanvantarikṣapaṇakāmarāsiṃhaśaṅku
vetālabhaţţa ghaţakarpara kālidāsāḥ |
khyāto varāhamihīro nṛpate sabhāyāṃ
ratnāni vai vararucirnava vikramasyā ||

The names of the nine gems and their traditional claims to fame are the following:

Dhanvantari (a medical practitioner), Kshapanaka (probably Siddhasena, a Jain monk, author of Dvatrishatikas), Amarāsimha (author of Amarakosha, a thesaurus of Sanskrit), Sanku (little known), Vetalabhatta (a Maga Brahmin known as the author of the sixteen stanza Niti-pradeepa (the lamp of conduct) in tribute to Vikramāditya), Ghatakarpara (author of Ghatakarpara-kavya (in which a wife sends a message, reverse of Meghaduta)), Kālidāsa (a renowned classical Sanskrit writer, widely regarded as the greatest poet and dramatist in the Sanskrit language), Varāhamihīra (astrologer and astronomer), and Vararuchi (poet and grammarian).

FIGURE 12 THE FIRST COUNCIL OF NICAEA, 325 CE



Nicaea, The first council of, The First Council of Nicaea was a council of Christian bishops convened in Nicaea in Bithynia (present-day İznik in Turkey) by the Roman Emperor Constantine I in CE 325. The Council was historically significant as the first effort to attain consensus in the church through an assembly representing all of Christendom. This was of great relevance to the evolution of the western Calendar, since one of its

accomplishments was the decision to settle the calculation of Easter.

Nididhyasanam - the final step of the 3 step process of sravaṇam, mananam, nididhyasanam, involves deep meditation and requires mumukshutwa and titiksha.

Nirayana means sidereal.

Nirukta - this treatise was authored by *Yāska* and deals with Etymology, a branch of Linguistics, the study of the roots of all words, made simpler by the intentional highlighting of Dhātu in Sanskrit. *Yāska* is one of the bright galaxy among the plethora of broad spectrum philosophers in the ancient Vedic era, who counted numerous skills in their repertoire linguistics being just one of their many fields of expertise.

Nighantu - *Yāska*'s Vedic Glossary, Nirukta is a commentary on the Nighantu.

Nirvana - blown out or extinguished as in the case of a lamp. Nirvana is generally used to refer to a material life that has been extinguished, i.e. for one who has achieved freedom from rebirth. The term Nirvana is commonly used in Buddhism as the final stage a practitioner strives for. The word does not mean heaven and is analogous to Moksha in the Sanātana Dharma.

Nychthemeron the natural day and night or space of twenty-four hours. Webster's Revised Unabridged Dictionary published 1913 by C. & G. Merriam Co.

O

Opposition – The appearance of two celestial bodies at opposite locations, on the ecliptic, separated by 180^{o}

Obliquity –The angle between the planes of the celestial equator and the ecliptic

Oblique ascension - The arc of a celestial equator, expressed in units of arc at a time that rises above an observer' horizon.

P

Padma-Purāṇa, This Purāṇa generally stands second in the list of Purāṇas, and is thus described: - "That which contains an account of the period when the world was a golden lotus (padma), and of all the occurrences of that time, is, therefore, called Padma by the wise. It contains 55,000 stanzas." The work is divided into five books or Khandas: -"

(1.) Srishti Khanda or section on creation;

(2.) Bhumi Khanda on the earth;

(3.) Swarga Khanda, on heaven;

(4.) Pātāla Khanda, on the regions below the earth;

(5.) Uttara Khanda, last or supplementary chapter.

(6.) There is also current a sixth division, the Kriya-yoga-sara, a treatise on the practice of devotion."

These denominations of the various divisions convey but an imperfect and partial notion of their heterogeneous contents, and it seems probable that the different sections are distinct works associated together under one title. The tone of the whole Purāṇa is strongly Vaishnava; that of the last section especially so. In it Siva is represented as explaining to Pārvati the nature and attributes of Vishnu and in the end the two join in adoration of that deity. A few chapters have been printed and translated into Latin by Wollheim.

Paleolithic Age is an early part of the Stone Age. The **Paleolithic** or **Palaeolithic Age**, Era, or Period, or **Old Stone Age**, is a prehistoric era distinguished by the development of the first stone tools, and covers roughly 99% of human history. It extends from the introduction of stone tools by hominids such as *Homo habilis* 2.5 or 2.6 million years ago, to the introduction of agriculture and the end of the Pleistocene around 10,000 BC. The PaLeolithic era ended with the Mesolithic, in Western Europe, and with the EpipaLeolithic in areas not affected by the Ice Age (such as Africa). The term *Paleolithic* was

coined by archaeologist John Lubbock in 1865. It derives from Greek: παλαιός, *palaios*, "old"; and λίθος, *lithos*, "stone", literally meaning "old age of the stone" or "Old Stone Age." The other eras that anthropologists use are the **Mesolithic** and **Neolithic.** All these eras occur before the advent of recorded history.

Pancha, Sanskrit term for five e.g. Panchabana, Panchatantra

Panchānga, पंचांग, **(Panchāngam)** The indigenous Indian Hindu calendar, consisting of 5 parts, see chapter I, section on Panchānga.

Parampara, परम्परा, tradition, as in likhita Parampara (written tradition), srauta Parampara (oral tradition), denotes a succession of teachers and disciples in the Indic tradition. It is also known as *Guru-Shishya Paramparā*, succession from Guru to disciple. In the paramparā system, knowledge (in any field) is passed down (undiluted) through successive generations. The Sanskrit word literally means *an uninterrupted series or succession*. In the traditional residential form of education, the shishya remains with his guru as a family member and gets the education as a true learner.

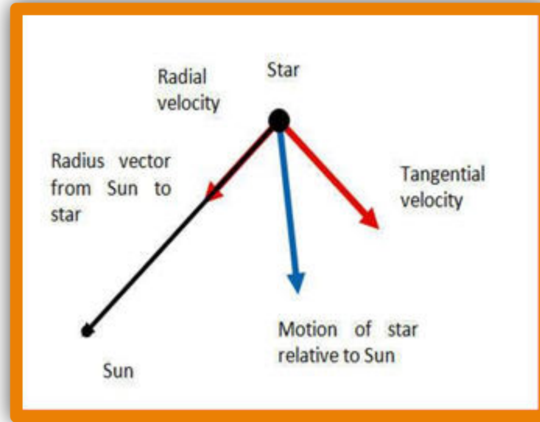


FIGURE 13 THE PROPER MOTION OF STARS

These traditions arose in various Gurukulas and in the universities of India such as Takšașīla, Vikramșīla, Odāntipura and the most famous example of them all was the University at Nalanda. The freedom of thought prevalent in the ancient world of India remains an impressive legacy rivaled only in the occident by the schools in the modern era , such as the Chicago school of Economists or the famous schools of Germany such as Gottingen and the most recent examples such as the University of California at Berkeley. There is no record in ancient India of a Savant in science being threatened with beheading unless he changed his views. This is solely a characteristic of the Occident without parallel in ancient India. In some traditions there is never more than one active master at the same time in the same *guruparamparaya* (lineage).

The fields of knowledge taught may include, for example, spiritual, artistic (music or dance) or educational. Titles of Gurus in a Parampara - In a parampara, not only is the immediate guru revered, the three preceding gurus are also worshipped or revered. These are known variously as the *kala-guru* or as the "four gurus" and are designated as follows;

Guru - the immediate guru or teacher/mentor also the name of the planet Jupiter or Brihaspati.

Parama-guru - the Guru's guru.

Parameșvara (1380-1460) residence Alattur, in Kerala, Nationality Indian, Ethnicity Namputiri, Occupation Astronomer-mathematician, Notable works DrgGaṇita, Goladipika, Grahana mandala, Known for Introducing the DrgGaṇita system of astronomical computations, Religion Hindu.

Parampara-guru - the Parama-guru's guru.

Paramești-guru-the-Parampara-guru's guru.

Paridhi - Circumference.

Pāda, Quadrant.

Perigee, Perihelion-(see also Apogee and Aphelion) the point in the orbit of an object (as a satellite) orbiting the earth that is nearest to the center of the earth; *also*: the point nearest a planet or a satellite (as the Moon) reached by an object orbiting it — compare apogee. Depending on when the perihelion

occurs during the calendar year, there would be major changes in the weather patterns. Perihelon and Aphelion are used specifically for solar orbits. Perigee and Apogee are the generic names that apply for any elliptical orbit.

Place Value System, स्थान the most common Sanskrit word for this is sthana which literally means place, and refers to the decimal system of numbers where the value of a number is determined by its location with respect to other numbers to the right, e.g. 3 followed by a 0, means the number is thirty.

Planets One of the first observations that the ancients made was that certain objects in the sky wandered in the sky among the fixed stars and the Greeks named these wanderers Planetai.

Pūrnima, **पूर्निम** full Moon

Pope Gregory XIII (Ugo Bioncompagni, 1502 – 1585) sent missionaries to India (and China) mainly to learn from the Namputhiris of Kerala. He suppressed knowledge that did not agree with the church dogma and also issued a proclamation that no knowledge, regardless of its source, be attributed to other than Catholics. In other words he flouted the concept of intellectual property with impunity and indulged in large scale larceny of intellectual property by not giving any attribution. The Gregorian Calendar was fixed shortly thereafter (subsequent to the return of the Jesuits from Malabar) but rarely is there mention that Matteo Ricci[296] expressed his objective of going to India and that he went there to learn the intricacies of Jyotiṣa and navigation.

Pramāṇa, प्रमाण, the literal meaning is rendered as right measure, scale, and standard. The semantic meaning is interpreted as means of correct knowledge, irrefragable proof. It forms one part of a tripuṭi (त्रिपुटि, trio) comprising Pramā (*the correct knowledge of any object arrived at by thorough reasoning*, Sanskrit), namely,

Pramātā (< pramātṛ), the *subject*, the knower
Pramāṇa, the *means* of obtaining the knowledge
Prameya, the *object*, the knowable

Prāmānya, Episteme, the theory of knowledge. The systematic study of the theory of knowledge goes back to great antiquity and the names associated with these disciplines include among others **Pāṇini, Patańjali (पतञ्जलि)**, **Yājnavalkya, and Bhartṛhari.** It is our contention that most if not all of these savants lived in the millennia prior to the Christian era.

Pratimaṇḍala, Prattivṛtta – the orbital circle of the eccentric (deferent).

Precession of the Equinoxes (see also Ayanachalana, equinox) - The earth revolves around the Sun once in **365^d 5^h 48^m 46^s**. Considered from the earth, the Sun appears to complete one round of the ecliptic during this period. This is called a tropical year. In the span of a tropical year; the earth regains its original angular position with the Sun. It is also called the year of seasons since the occurrence and timing of seasons, depends on this Earth-Sun cycle. If we consider the revolution of the Sun around the earth from one vernal equinox (around 21st March, when the day and night all over the globe are equal) to the next vernal equinox, it takes one tropical year to do so. However, if at the end of a tropical year from one vernal equinox to the next, we consider the position of the earth with reference to a fixed star of the Zodiac, the earth appears to lie some 50.26 seconds of celestial longitude to the west of its original position. In order for the earth to attain the same position with respect to a fixed star after one revolution, it takes a time span of **365^d 6^h 9^m 9.8^s**. This duration of time is called a sidereal year. The sidereal year is just over 20 minutes longer than the tropical year. Each year, the Vernal equinox will fall

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[295] *Letter by Matteo Ricci to Petri Maffei on Dec 1, 1581, Goa 38 I, pp.129r-130v, corrected and reproduced in Documenta Indica, XII, 472-477 (p 474). Also reproduced in Tacchi Venturi, Matteo Ricci S.J, La Lettre Dalla Cina 1580-1610, vol.2, Macareta, 16l3. Ricci states 'Com tudo no me parece que sera impossivel sabers, mas has de ser por via d'algum mouro honorado ou brahmane muito intelligente que saiba as cronicas dos tiempos, dos quais eu procurarei saber tudo '.I am trying to learn about the methods of reckoning time from 'an intelligent Brahman or an honest Moor.*

short by 50.26 arc seconds along the Zodiac reckoned along the fixed stars. This continuous receding of the Vernal equinox along the Zodiac is called the Precession of the equinoxes.

Proper Motion- the motion of a purportedly fixed star in the direction tangential to the radial vector emanating from the Sun to the fixed star in figure 15, the tangential velocity is the vector defining the proper motion of the distant star.

Proto-Indo-European - **PIE** for short is a constructed language for which there is no existence theorem. It is based on unproven and unverifiable hypothesis.

Proto Dravidian - the alleged hypothetical ancestor language to the modern languages of Telugu, Tamil, Kannada, Tulu, and Malayalam. Again there is no proof that a single human ever spoke the language. There is no reference to such a language in any of the vast literary works of India south or north. It is entirely a construct of the Occidental to create distinctions where there were none. This is not to say that there was no independent development of languages in the South. In fact it is our contention that the codification of a language over a larger area takes place only after the Prakrits have established themselves over a larger area, and that there is no reason to consider the languages of the south as being in a different category than the Prakrits of the north. It should come as no surprise that Malayalam has a vocabulary that is 70% Sanskrit, and that percentage is rather high in all of the South Indian languages including the language that has become synonymous with Dravidian, namely Tamil. The result of this is that the exchange of vocabulary became a two way street, as was the exchange of people.

Purāṇa, पुराण - literally means the ancients. Traditional Sanskrit texts dealing with diverse topics such as the creation of the world, legends, genealogy of sovereigns, In the Indic context, Purāṇas have special significance both from a temporal stand point and from a historical perspective. That there are embellished stories within the Purāṇa does not detract from the considerable amount of material that can be used to decipher the past. The Purāṇas are supposed to embody 5 attributes or Pancha Lakshana, see for instance, the Appendix D on the Purāṇas.

Pūrnimanta (see also Amanta) Indian Lunar calendar where the month begins and ends on Pūrnima (Full Moon). The obverse, where the month begins after **Amāvāsyā, new** Moon is called an Amanta calendar.

Puruṣa, Pauruṣeya, and Apauruṣeya - In Hinduism, Puruṣa ("Cosmic Man") is the "self" which pervades the universe. The Vedic divinities are considered to be the human mind's interpretation of the many facets of Puruṣa. According to the RV Puruṣa sukta, Puruṣa was dismembered by the devas, the different senses and sense organs formed the Solar System-- his mind is the Moon, his eyes are the Sun, and his breath is the wind. In Saṇkhya, a school of Hindu philosophy, Puruṣa is pure consciousness. It is thought to be our true identity, to be contrasted with Prakrti, or the material world, which contains all of our organs, senses, and intellectual faculties. A more restricted meaning of Puruṣa is youth or human (paurusheya).Hinduism in that sense is an Apauruṣeya belief system as opposed to the revealed or prophetic faiths such as Judaism, Christianity, or Islam which would therefore come under the category of paurusheya religions. The Paurusheya religions are those based on a Prophet (he plays the role of intermediary or middle man between the individual and God). Despite the fact that they were composed by well known Rishis, the emphasis in the Indic Darshanas has never been on the Identity of the Rishi. This is in marked contrast to the Abrahamic faiths where the role of the Prophet is central to the notion of a Religious dogmatic faith. In reality it is the prophetic religions that are by their very nature dogmatic, exclusivist and till recently were extremely bigoted. It is the Apauruṣeya aspect of Hinduism that makes the notion of Hindu fundamentalism a non sequitur and an oxymoron. Hindu fundamentalism, when juxtaposed against the exclusivist aspects of Abrahamic faiths, simply does not exist.

Puruṣārtha - Puruṣartha or Manushyārtheha is the pursuit of the four kinds of human aspirations, which

are Dharma, Artha, Kāma, and Moksha. The four pursuits in which humans may legitimately engage, also called chaturvarga, "four-fold good", is a basic principle of Hindu ethics.

Pūrvapakṣa -new Moon to full Moon period

Pramāṇa Epistemology प्रमाणं the process of gaining knowledge, sometimes used to express the goal as well as the means to attain knowledge, as in āpauruṣeya pramāṇam .The word is used in slightly different contexts also.

As in the Bhagvad Gita

यद् यदाचरति श्रेष्ठस्तत्तदेवेतरो जनः ।

स यतप्रमाणं कुरुते लोकस्तदनुवर्तते ।। BG 3- 21 ।।

Yad yadācharati Śreşţhas tat tadeve taro janaĥ |

SA yat pramāṇam kurute lokastadanuvartate ||

Translation: Yad Yad -whatsoever, charati-he behaves, he practices, SreShThas- best, most splendid, most excellent, eva - indeed , used as a rhythmic filler, Itarah - the other, janah - people, sah - he , yat - what, Pramāṇam- measure, scale , standard, Kurute - does, lokah - the world, tat - that, this, Anuvartate - it follows

Whatever a great man does, is followed by others, whatever example he sets, the world follows that.

Prāsthanatrāyi, literally, three points of departure, refers to the three canonical texts of Hindu philosophy, especially the Vedanta schools. It consists of: the Upanishads, known as Upadesha prasthana (injunctive texts), the Brahma Sūtras, known as Nyāya prasthana (logical text), the Bhagavad Gita, known as Sadhana prasthana (practical text).

Pratyakṣa, प्रत्यक्ष -*Pratyakṣa Pramāṇa:* This is called direct proof, as it is perceived by the sense organs. These organs are only instruments. The mind enters them and helps them to function. There are some limitations on the senses like disease and imperfection that make proof obtained by this method to be infirm. For example, a normal eye can see all colors; a jaundiced eye sees everything as yellow. Though the *laddu* is sweet, the tongue of a malaria patient classifies it as bitter. Here, there are two points of view. From the point of view of the matter it is sweet. But from the point of view of the senses it is bitter. It can be concluded, therefore, direct proof is not complete evidence for real justice.

Puskaramadityo: "lotus of the sky" (sun)

Punarvasu: Castor and Pollux

R

Rajas - Rājasik individuals are filled with a desire and passion to undertake new projects and goad others into action. Many leaders exhibit an Rājasik temperament

Raja Yoga - Raja Yoga, as outlined by Patańjali, describes eight "limbs" of spiritual practices, half of which might be classified as meditation. Underlying them is the assumption that a yogi should still the fluctuations of his or her mind: *Yoga chittavrrti nirodha.*

Rāmāyaṇa रामायण, Rāmāyaṇa- a Hindu epic in which Rama, avatar of Vishnu vanquishes Ravana and is reunited with his spouse Sita.

Rāśi – राशि, **a** sign in the tropical Zodiac, also denotes a 30^{o} division of the Zodiac

Rationalism – the view that knowledge can be acquired other than through the use of the senses, by exercise of our unaided powers of reasoning. This forms the basis of proof in the Indic episteme, upapatti, or Yukti.

Rasabha ("Twin asses"): Gemini

Ṛg Veda ऋगवेद - The earliest and the most prominent of the Vedas, the compositions of the Ancient Indics who we will refer to also as the Vedics, held to be sacred and termed Śruti by many Hindus, the

chief characteristic was their oral tradition.

The Antiquity of the Veda

It is well known that in the RV, the honor of the greatest and the holiest of rivers was not bestowed upon the Ganga, but upon Sarasvati, now a dry river, but once a mighty flowing river all the way from the Himalayas to the ocean across the Rajasthan desert. The Ganga is mentioned only once, while the Sarasvati is mentioned at least 60 times. Extensive research by the late Dr Wakankar has shown that the Sarasvati changed her course several times, going completely dry around 1900 BCE The latest satellite data combined with field archaeological studies have shown that the Ṛg Vedic Sarasvati had stopped being a perennial river long before 3000 BCE.

This was the Sarasvati described in the RV. Numerous archaeological sites have also been located along the course of this great prehistoric river thereby confirming the Vedic accounts. The great Sarasvati that flowed from the mountain to the sea is now seen to belong to a date long anterior to 3000 BCE. This means that the RV describes the geography of north India long before 3000 BCE. All this shows that the RV must have been in existence no later than 3500 BCE.
The Ganga is mentioned only once, while the Sarasvati is mentioned at least 60 times.

River Sarasvati in RV

The river called Sarasvati is the most important of the rivers mentioned in the RV. The image of this great goddess stream dominates the text. It is not only the most sacred river, but also the goddess of wisdom. She is said to be the mother of the Vedas. A few of the 50 Ṛg Vedic hymns which mention Sarasvati River are presented below:

Ambitame naditame devitame sarasvati (II.41.16)
(The best mother, the best river, the best Goddess, Saraswati)
Maho arnah saraswati pra chetayati ketuna dhiyo visva virajati (I.3.12)
(Saraswati like a great ocean appears with her ray, she rules all inspirations)
ni tva dadhe vara a prthivya ilayspade sudinatve ahnam:
drsadvatyam manuse apayayam sarasvatyam revad agne didhi (III.23.4)
(We set you down, oh sacred fire, at the most holy place on Earth, in the land of Ila, in the clear brightness of the days. On the Drishadvati, the Apaya and the Saraswati rivers, shine out brilliantly for men)
citra id raja rajaka id anyake sarasvatim anu;
parjanya iva tatanadhi vrstya sahasram ayuta dadat (VIII.21.18)
(Splendor is the king; all others are princes, who dwell along the Saraswati river. Like the Rain God extending with rain he grants a thousand times ten thousand cattle)
Saraswati like a bronze city: **ayasi puh;**
surpassing all other rivers and waters: **visva apo mahina sindhur anyah;**
Pure in her course from the mountains to the sea: **sucir yati girbhya a samudrat (VII.95.1-2)**

All this indicates that the composers of the Vedic literature were quite familiar with the Sarasvati River, and were inspired by its beauty and its vastness that they composed several hymns in her praise and glorification. This also indicates that the Vedas are much older than the MBH period which mentions Sarasvati as a dying river.

Right Ascension, Prakjyakashta, RA of a star or any other celestial body (given by the lower-case Greek

letter alpha) is the angle the body makes with the vernal equinox as measured to the east, again along the celestial equator. The modern value is usually measured in time units, reflecting the equivalence between a 24 hour day and a 360^o diurnal rotation of the earth during this period.

Roma people - The name that the Gypsies are known by in Europe, reflecting their large numbers in Romania.

Roots of the Quadratic Equation, In the Vedic mathematical sutras, calculus comes in at a very early Ṛstage. As it so happens that differential calculus is made use of in the Vedic sutras for breaking a quadratic equation down at sight into two simple equations of the first degree and as we now go on to our study of the Vedic sutras bearing on quadratic equations, we shall go into the reasons as to why the calculus was stage brought in at a very early stage in Indic antiquity.

Rotation is the motion of a celestial body around its own axis, for example the Earth in a day; contrasted with Revolution.

S

Saṃhita (Sanskrit "joined" or "collected") may refer to"the basic metrical (mantra) text of each of the *Vedas*

Specifically, these texts with sandhi applied

Post-Vedic texts known as Saṃhita:

Ashtavakra Gita

Bhrigu Saṃhita

Brahma Saṃhita

Deva Saṃhita

Garga Saṃhita

Kashyap Saṃhita

Shiva Saṃhita

Yoga Yājnavalkya Saṃhita

Sāmpradāya, **सांप्रदाय** In Hinduism, an Sāmpradāya is a tradition encompassing a common Philosophy but embracing many different schools, groups, or guru lineages (called Parampara). By becoming initiated (diksha) into a parampara one automatically belongs to its proper sāmpradāya.

Sankaracharya, संकराचार्य The great proponent of Advaita Vedanta ,the founder of the Dasanami order. Bhagvatpada Acharya Sankara was a veritable institution masquerading as an individual. There is controversy over the date of his birth, ranging from 509 BCE to 788 CE

Sāṇkhya, **सांख्य** Sāṇkhya is considered to be the oldest among the philosophical systems dating back to about 700 BCE. Kapila, the author of 'Sāṇkhya Sūtra", is considered to be the originator of this system. The "Sāṇkhya Karika" of Ishwara Kṛṣṇa is the earliest available text on Sāṇkhya dating to about 300 CE. Sāṇkhya's name is derived from root word Sāṇkhya (enumeration) and is reflective than authoritative. Well-known commentaries are Gaudapada's bhasya, Vachaspati Misra's Tattwa-kaumudi, Vijnanabhiksu's Sāṇkhya Pravāchanbhāsya, and Mathara's Matharavrtti.

The Sāṇkhya system proposes the theory of evolution (Prakriti-Puruṣa) that is accepted by all other systems. The Puruṣa (soul) of this system is unchanging and is a witness to the changes of Prakriti. Hence the Sāṇkhya system is based on dualism wherein nature (Prakriti) and conscious spirit (Puruṣa) are separate entities not derived from one another. There can be many Puruṣas since one man can attain enlightenment while the rest do not, whereas Prakriti is one. It is identified with pure objectivity, phenomenal reality, which is non-conscious.

Prakriti possess three fundamental natures;

(1) The pure and fine Sattva (2) The active Rajas and (3) The coarse and heavy Tamas. Sattva accounts

for thought and intelligibility, experienced psychologically as pleasure, thinking, clarity, understanding, and detachment. Rajas accounts for motion, energy and activity and it is experienced psychologically as suffering, craving, and attachment. Tamas accounts for restraint and inertia. It is experienced psychologically as delusion, depression, and dullness.

The conscious Puruṣa excites the unconscious Prakriti and in this process upsets the equilibrium of the various guans. According to Sāņkhya there are twenty-five tatva which arise due to the union of Puruṣa and Prakriti. Their union is often described as the ride of a lame man with perfect sight (Puruṣa) on the shoulders of a blind person of sure foot (Prakriti). Their process of evolution is as given below and it accounts for the different tatva. In Sāņkhya creation is the development of the different effects from mulaprakriti and destruction their dissolution into mulaprakriti.

Sāņkhya is agnostic because it believes that the existence of god cannot be proved. Prakriti, the cause of evolution of world, does not evolve for itself but for Puruṣa-the ultimate consciousness. The self is immortal but due to ignorance (Avidya) it confuses itself with the body, mind, and senses. If Avidya is replaced by vidya the self is free from suffering and this state of liberation is called kaivalya. Yoga is the practical side of Sāņkhya.

Saṃkrāṇti - The time when the Sun crosses from one Rāśi sign to the next is called a Saṃkrāṇti and marks the beginning of the Solar month. Two well-known Saṃkrāṇtis are Makara Saṃkrāṇti or Pongal around January 14 and Meṣa Saṃkrāṇti on April 14. Meṣa Saṃkrāṇti marks the beginning of the New Year in Assam, Bengal, Kerala, Orissa, and Tamil Nadu — these states follow a purely Solar calendar for fixing the length of the year.

Sanskrit, Saṃskrtam संस्क्रतम, The adjective saṃskṛta means "refined, consecrated, sanctified". The language referred to as saṃskṛta vāk "the refined language" has by definition always been a 'high' language, used for religious and scientific discourse and contrasted with the languages spoken by the people.

Saṃhitās साम्हिता are a collection of sacred hymns in Sanskrit constituting one of the four Vedas.

Saptarishi, **सप्तरिशि** is the Indian name for the Ursa Major constellation. The saptariṣi play a major role in Hindu astronomy. A number of yugas In Hindu philosophy, the cycle of creation is divided into four Yugas (ages.): Satya Yuga or Krita Yuga, Treta Yuga, Dvāpara Yuga, Kali Yuga make a Manvantara. Each Manvantara has a set of seven Riṣis who help in preserving order and propagating knowledge in that Manvantara. The metaphor of the Sapta rishi keeping order in the skies is very apt.

Sara or Utkramjya is the Sanskrit term for Versine

Saros Cycle the period of 223 synodic months over which the eclipses repeat themselves.

Bharadwaja is one of the seven Riṣis of the Vaivasvata Manvantara. The other six Riṣis of the Vaivasvata Manvantara are **Atri** in Hinduism; Atri is a legendary bard and scholar, and a son of Brahma. **Jamadagni** is the father of Parashurama, one of the avatars of Vishnu. King Kārtavīrya Arjuna and his army visited Jamadagni, who fed his guest and the whole army with his divine cow; the king demanded the cow and Jamadagni refused because he needed the cow for his religious ceremonies. King Kārtavīrya Arjuna sent his soldiers to take the cow and Parashurama killed the entire army and the king with his axe (given to him by Shiva). In return, the princes beheaded Jamadagni. In revenge, Parashurama destroys large numbers of the Kshatriyas. **Mahārishi Viswāmitra** is one of the seven venerated sages of Hindu mythology. He is a Kshatriya (Warrior caste) by birth, but has transcended into the Brāhmaṇa priestly caste with his tough penance.

Vašişţa, in Hindu mythology was chief of the seven venerated sages (or saptariṣi) and the Raja guru of the Solar Dynasty. He was famous for subduing the armies of Viswāmitra. He had in his possession the divine cow Nandini who could grant anything to her owner.

Gautama and Kashyapa: Kashyapa ("tortoise") is an ancient god (one of the Riṣis), father of the devas;

Asuras, Nagas and all of humanity. He is married to Āditi, with whom he is the father of Agni and the Ādityas. He received the spoils of Parasurama's conquest of King Kārtavīrya Arjuna.

Sapta Saindhava, सप्त सैन्धव – Land of the seven rivers has been generally identified as Punjab by the modern scholars. Rulers of the western lands, the Druhyus and the Anus, preserved the RV and helped the Puru Bharatas in building a Dhārmic empire.

The **Sātavāhanas** also known as **Andhras** (Telugu:□□□□□□□□□□, Prakrit/Pro-Marathi:सातवाहन), were a dynasty which ruled the Magadha empire from 833 BCE to 327 BCE. Later descendants ruled from Junnar (Pune), Prathisthan (Paithan) in Mahārashtra and Amaravati (Dharanikota) in Andhra Pradesh over Southern and Central India from around 230 BCE onward. (see Proposed chronology)

Sattva, सत्व - Individuals who are predominantly Sāttvic are attached to happiness and to knowledge

Satya, Ṣuddhi -truthfulness in thought and speech

Ṡāstra or Shāstra. or Sastra शास्त्र Ṡāstra is a Sanskrit word used to denote education/knowledge in a general sense. The word is generally used as a suffix in the context of technical or specialized knowledge in a defined area of practice. For example, Astra Ṡāstra means, knowledge about "Handling of weapons". Astra means weapons, and Ṡāstra is their knowledge. Extending this meaning, the Ṡāstra is commonly used to mean a treatise or text written in explanation of some idea, especially in matters involving religion. In Buddhism, a Ṡāstra. is often a commentary written at a later date to explain an earlier scripture or Sūtra. In the Indonesian language, 'Sastra' is a word meaning 'literature'.

Ṣabda Pramāṇam (Bhartṛhari) See Bhartṛhari[297]

Ṣanku Yantra – gnomon an instrument first used by Āryabhaţa to measure and compute the value of a sidereal day

Ṡatapatha Brāhmaṇa, (शतपथ ब्राह्मण) Brāhmaṇa of one-hundred paths - is one of the prose texts describing the Vedic ritual. It belongs to the vājasaneyi madhyandina shakha of the White Yajurveda. It survives in two recensions, Madhyandina and Kanva, with the former having the eponymous 100 Brāhmaṇas in 14 books, and the latter 104 Brāhmaṇas in 17 books. Linguistically, it belongs to the Brāhmaṇa period of Vedic Sanskrit, dated by Western Indologists to the first half of the 1st millennium BC. Hindu scholars have dated it to around 1800 BC, based on the reference in it of migration from the Sarasvati river area to east India, because the river is said to have dried up around 1900 BC. The 14 books of the Madhyandina recension can be divided into two major parts. The first 9 books have close textual commentaries, often line by line, of the first 18 books, of the corresponding Saṃhitā of the Yajurveda. The following 5 books cover supplementary and ritualistically newer material, besides including the celebrated Brihatāranyaka Upanishad as most of the 14th and last book. The celebrated author of the Ṡatapatha Brāhmaṇa is reputed to be **Yājnavalkya** himself. He is also reputed to have made the observation that the 95 year the Ṡatapatha Brāhmaṇa synchronization cycle provides an accurate measure of the repeatability of Lunar phenomena was translated into English by Prof. Julius Eggeling, in the late 19th century, in 5 volumes published as part of the Sacred Books of the East series. Retrieved from
"http://en.wikipedia.org/wiki/Ṡatapatha Brāhmaṇa"

Saura – adjectival form of Sūrya, pertaining to the Sun.

Shakti, **शक्ति** the female energy principle, in the Indic tradition, the primordial icon of strength and energy is associated with the feminine gender

Ṣānti - peace of mind attained through the disciplines of Raja Yoga **Shaucha** – cleanliness

Sāvana – Civil as in Sāvana dIna, Civil Day

297 Bhartṛhari, Śabda, a study of Bhartṛhari's Philosophy of Language, DKPrintworld, Delhi, by Tandra Patnaik,2nd edition,2007

Scholia (singular, **scholion**; from Greek Greek: σχόλιον "comment", "lecture"), are grammatical, critical, or explanatory comments, either original or extracted from pre-existing commentaries, which are inserted on the margin of the manuscript of an ancient author, as glosses. One who writes Scholia is a **scholiast**.

Sidereal With reference to the distant star.

Sidereal Day - Nakṣatra **divas**, a mean sidereal day is about 23h56m in length. Due to variations in the rotation rate of the Earth, however, the rate of an ideal sidereal clock deviates from any simple multiple of a unit of time.

Sidereal Month - Sidereal month The actual period of the Moon's orbit as measured in a fixed frame of reference is known as a sidereal month, because it is the time it takes the Moon to return to the same position on the celestial sphere among the fixed stars (Latin: sidus): 27.321661 days (27d 7h 43m 11.6s) or about 27 ⅓ days. This type of month has appeared among cultures in the Middle East, India, and China in the following way: they divided the sky in 27 or 28 lunar mansions, characterized by asterisms (apparent groups of stars), one for each day, of the sidereal month. That the Moon follows its track among the stars. The sidereal month is thus, about two day shorter (27.3217) than the Synodic month.

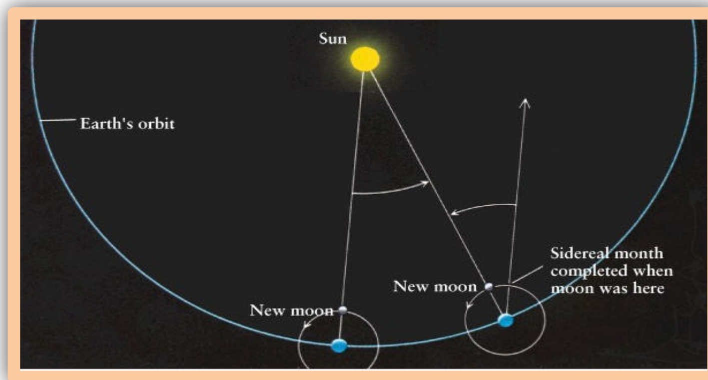


FIGURE 14 THE SIDEREAL MONTH

Figure showing the mechanism to explain the difference between Sidereal Month and a synodic month, since during the 27 Days the earth has rotated about 1/12th of its orbit around the Sun and hence the Moon has to rotate another 1/12th around the earth in order to stay in alignment between the Sun and the earth.

Sidereal Orbit is a revolution relative to a fixed celestial position.

Sidereal Noon is the instant of transit of mean equinox relative to a fixed meridian position.

Sidereal Time - During the course of one day, the earth has moved a short distance along its orbit around the Sun, and so must rotate a small extra angular distance before the Sun reaches its highest point. The stars, however, are so far away that the earth's movement along its orbit makes a generally negligible difference to their apparent direction (see, however parallax), and so they return to their highest point in slightly less than 24 hours. A mean sidereal day is about 23h 56m in length. Due to variations in the rotation rate of the Earth, however, the rate of an ideal sidereal clock deviates from any simple multiple of a civil clock.

Sidereal Year - In order for the earth to attain the same position with respect to a fixed star after one revolution, it takes a time span of **365^{d} 6^{h} 9^{m} 9.8^{s} (365.2563634259**) . This duration of time is called a

sidereal year. The sidereal year is just over 20 minutes longer than the tropical year; this time difference is equivalent to 50.26 seconds of celestial longitude. Each year, the Vernal equinox will fall short by 50.26 seconds along the Zodiac reckoned along the fixed stars. These numbers are not invariant with time and there is a secular decrease in both the sidereal year as well as the amount by which the vernal equinox precesses each year, throughout the centuries. This may explain why Āryabhaţa computed higher value for this number. In fact this could be means to determine the age of the Āryabhaţīya.

Śīgroccha - apex of fastest motion, the modern term for this is Perigee or Perihelion, which is used specifically in the context of elliptic orbits. During the time of the ancients, they were not aware of the elliptic nature of the orbits.

Sighra samskara – correction applied after calculating madhyama Graha and manda samskara

Smrti, स्मृति means that which is remembered. There are a number of texts that are specifically classed as Smrti and are mostly named after the name of the Riși expounded on the Smrti such as Parasara Smrti, Manu Smrti, and Yājnavalkya Smrti.

Solar Day - Solar time is measured by the apparent diurnal motion of the Sun, and local noon in Solar time is defined as the moment when the Sun is at its highest point in the sky (exactly due south in the northern hemisphere and due north in the southern hemisphere). **The time taken for the Sun to return to its highest point is by definition exactly 24 hours, or a Solar day.**

Solar Month (सौर मास(- A Solar month (30.438229707 days as per Sūrya Siddhānta, 30.438030, Modern value) is the time taken for the Sun to pass through one of the twelve segments1) /12 of a **Sidereal year**).



FIGURE 15 A SUN'S PASSAGE OVER NORTHERN HEMISPHERE
A COMPOSITE PICTURE OF THE WINTER SOLSTICE OVER THE TYRRHENIAN SEA
TAKEN BY DANILO PIVATO DURING THE WINTER SOLSTICE DECEMBER 21, 2005

Solstice – अयनन्त etymology, from Latin solstitium, comprising two words: sol "sun" + stitium "stoppage" from sistere "come to a halt, stop". The implication of the Latin word is "the time when the Sun stands still". The moment when the Sun is farthest from the equator. In the northern hemisphere, the summer solstice occurs around June 21 and the winter solstice about December 21. In 2007 the winter solstice occurred at December 22. The summer solstice marks the longest day of the year; the winter solstice, the shortest. See also Equinox, cardinal points.

Spaṣṭagati, sphutagati – true motion of a planet
Spaṣṭagraha - True Planet
Spaṣṭasūrya, sphutasūrya – true sun
Sphuta – true planet often be used as a Prefix, such as Sphuta Sūrya or the true Sun. This definition arises because, there was need to determine the true longitude of the Sun as opposed to the Manda, which is obtained using the assumption of a uniform angular motion of the Sun. The mean and the true locations will be identical only at the 2 equinoxes.
Sphutakriya- The method by which the computation of the true planet is devised.
Śramana tradition - A Śramaṇa is one who performs acts of mortification or austerity. According to the definition, a being is himself responsible for his own deeds. Salvation, therefore, can be achieved by anybody irrespective of caste, creed, color, or culture. The cycle of rebirth to which every individual is subject is viewed as the cause and substratum of misery. The goal of every person is to evolve a way to escape from the cycle of rebirth, namely by discounting ritual as a means of emancipation and establishing from the misery of Samsāra, through pious religious activities. The term has been used in the past as a synonym for the Baudhik tradition.
Srauta Sūtras - Srauta is the adjectival form of Śruti (that which is heard) and is one of the 4 constituent Sūtras in the Kalpa Sūtra (see also Sulva Sūtra).

Sravaṇam, श्रवणम Comes from the same root as Śruti. Essentially means learning by listening. Śravanam, mananam, nididhyasanam is the 3 step process towards Brahma vidya and self realization. In reality it is the approach generally adopted to the study of most subjects especially those with complex concepts.

Śruti, श्रुति that which is heard as opposed to that which is remembered (Smrti). The Smrti were composed by famous Riṣis.

Sulva Sūtras, सुल्वसूत्र् The Sulva Sūtras (or Sulba Sūtras) or aphorisms of the cord (measurements were made using a string stretched between 2 pegs). The resulting mathematical manipulations needed to solve the problems of finding areas and volumes of reasonably complex shapes formed the subject matter of the Sulva Sūtras. The Sulva Sūtras were part of the Kalpa Sūtra appendices to the Veda. Kalpa Sūtra consisted of Grhya Sūtras, Srauta Sūtras, Dharma Sūtras, and Sulva Sūtras. The Kalpa Sūtras in turn are part of the Vedāńga (limbs of the Veda) comprising of Chandas (meter), Nirukta (etymology), Vyākarana Grammar, Jyotiṣa (Astronomy and astrology), and Kalpa Sūtras. 0ne set of such Sūtras are the Kalpa Sūtras which consisted of Srauta Sūtras, Dharma Sūtras, Grihya Sūtras and Sulva Sūtras. The Srauta Sūtras give elaborate rules for the performance of Vedic sacrifices; the Grihya Sūtras deal with domestic religious ceremonies; the Dharma Sūtras contain the rudiments of Hindu Law and the Sulva Sūtras form the earliest source of Hindu Mathematics.
Superior or Exterior Planets – Mars, Jupiter, and Saturn (Mangala, Guru or Brihaspati or Dyaus Pitr, Sani)
Sūryaprajnāpati - A Jaina astronomical treatise, which uses a 5 year lunisolar cycle. One of the great contributions of the Jainas to Astronomy and Mathematics in Ancient India. The Jaina tradition exhibited a very superior knowledge of the exact sciences when compared to similar civilizations of that period.
Sūrya rasmi: moon (TS)
Sūrya-Siddhānta (Sanskrit) (SS) A celebrated astronomical work of ancient India of enormous antiquity. This work shows marvelous mathematical skill and comes very close to the modern time periods of astronomy that the most skilled mathematicians and astronomers have determined. It also deals with yugas in their various lengths, divisions of time itself into infinitesimal quantities, and general astronomical subjects, including not only the time periods of the Sun, Moon, and planets, but also eclipses, seasons of the year, etc.
The *Sūrya-Siddhānta* states that it was dictated more than two million years ago, towards the end of the krita Yuga (golden age) by the Sun himself, through a projected Solar representative, to the great sage

Asuramaya who wrote down the revelation. It was known to Āryabhaţa and *Varāhamihīra.*

Sūtra (Sanskrit: सूत्र Sūtra, Devanagari: सूत्र, Pāli: sutta), literally means a thread or line that holds things together, and more metaphorically refers to an aphorism (or line, rule, formula), or a collection of such aphorisms in the form of a manual. One of the most famous definitions of a Sūtra in Indian literature is itself a Sūtra and comes from the Vayu Purāṇa:

alpākṣaraṃ asandigdhaṃ sāravath viśvatomukham
asathobhaṃ anavadyaṃ cha sūtram sūtravidho viduḥ

Of minimal syllabary, unambiguous, pithy, comprehensive, continuous, and without flaw: who knows the Sūtra knows it to be thus.

अल्पाक्शरम् असन्दिग्धम् सारवथ् विश्वथो मुखम्

असथोभम् अनवध्यम् च सुत्रम् सुत्रविधो विदुह्।

Those who know the definition of a Sūtra define it as possessing the following qualities.
alpākṣaraṃ = With bare minimum (use of) alphabets
Asandigdhaṃ = Free from doubts and ambiguities; clear and accurate
Sāravad = like the essence; devoid of unnecessary pulp
Viswatho mukham = Universal; applicable anywhere and everywhere. [Not limited by time, space, cultures etc.]
Asathobham = Shining, Illuminating, highlighting the point at hand, never diminishing in radiance/value
Anavadyam = Without any bugs, errors, mistakes or shortcomings; perfect
Synodic Month is the period between 2 successive full Moons or new Moons
Szygy opposition and conjunction of Sun and Moon

T

Tamas - Tamas is inertia born of ignorance. It enshrouds the discrimination of man and inclines him to indolence, sleep *and renders him inert. By nature it is destructive.*
Tāragrahas Planets, Mercury, Venus, Mars, Jupiter, Saturn
Temporal Unit (TU) is 36,525 mean Solar days since Jan. 0.5, 1900, UT.
Terminus post quem : *Terminus post quem* and the related *terminus ante quem* are terms used to give an approximate date for a text. *Terminus post quem* is used to indicate the earliest point in time when the text may have been written, while *Terminus ante quem* signifies the latest date at which a text may have been written.

Terminus ante quem refers to the date **before which** an artifact or feature must have been made or deposited. Used with *Terminus post quem* ("limit after which"), similarly, *terminus ad quem* ("limit to which") may also refer to the latest possible date of a non-punctual event (period, era, etc.), while *terminus a quo* ("limit from which") may refer to the earliest such date.

For example an archaeological find of a burial may contain coins dating to 1588, 1595 and others less securely dated to 1590-1625. The *terminus post quem* would be the latest date established with certainty, the coin that may have only reached circulation in 1595. The burial can only be shown to be 1595 or later. A secure dating of another coin to a later date would shift the *terminus post quem*.

An archaeological example of a *terminus ante quem* would be deposits formed before or beneath a historically dateable event, such as a building foundation partly demolished to make way for the city wall known to be built in 650. It may have been demolished in 650, 649 or an unspecified time before - all that can be said from the evidence is that it happened before that event.

Either term is also found followed by Latin *non* **not**. An example is in the supposed language dating method known as linguistic palaeontology. This holds (very controversially) that if the ancestor language of a family can be shown to have had a term for an invention such as the plough, then this sets a *terminus ante quem non*, a time-depth *before* which that ancestor language could *not* have begun

diverging into its descendant languages. This has been used to argue against the Anatolian hypothesis for Indo-European because the date it implies is too early in that it violates the *terminus ante quem non*.

Theon of Alexandria (Greek: Θέων, ca. 335 - ca. 405 AD) was a Greek scholar and mathematician who lived in Alexandria, Egypt. The biographical tradition (Suda) defines Theon as "the man from the Mouseion"; actually, both the Library of Alexandria and the Mouseion may have been destroyed a century before by the Emperor Aurelian during his struggle against Zenobia. Some scholars think that they were closed by the patriarch Theophilus on order of the Christian Roman emperor Theodosius I in 391 AD. Theon was the father of the mathematician and pagan martyr Hypatia of Alexandria whose murder is attributed by Socrates Scholasticus to "political jealousy" which instigated mob violence. Theon's most durable achievement may be his edition of Euclid's *Elements*, published around 364 and authoritative into the 19th century. The bulk of Theon's work, however, consisted of commentaries on important works by his Hellenistic predecessors. These included a "conferences" (*Synousiai*) on Euclid, and commentaries (*Exegeseis*) on the *Handy Tables* and *Syntaxis* of Ptolemy, and on the technical poet Aratus.

Tilak, Bal Gangadhar, One of the Polymaths of modern India. It is these individuals with intellectual capabilities that the Colonial power found threatening to their rule in India, and found it necessary to send him to exile in Rangoon, on the flimsy pretext that he had committed sedition against the Imperial Power.

Tithi/ Lunar Day - The area covered by the Moon in its transit away from the Sun, computed for the moment of its conjunction with Sun to its true longitude at the moment of the epoch. It is obtained by subtracting the Longitude of the Sun from the longitude of the Moon. A Tithi is completed when the longitude of Moon gains exactly 12 degrees or its multiple on that of Sun and therefore there are 30 Tithis in a Lunar month. Is the root of the word atithi which means guest in Sanskrit (meaning one who may show up at any time or day but should be welcomed regardless).
http://en.wikipedia.org/wiki/Tithi

Titiksha (Sanskrit) - [from the verbal root *tij* to urge, incite to action, be active in endurance or patience]. Patience, resignation, endurance; not mere passive resignation, but an active attitude of patience in supporting the events of life. Mystically, the fifth state of raja yoga -- "one of supreme indifference; submission, if necessary, to what is called 'pleasures and pains for all,' but deriving neither pleasure nor pain from such submission -- in short, the becoming physically, mentally, and morally indifferent and insensible to either pleasure or pain" (VS 93). The meaning however is not of a cold, heartless, impassive attitude towards the sufferings of others, but an active positive attitude, so far as one's individual pleasures or pains are considered, but likewise involving an active attitude of compassion for the tribulations and sufferings of others. The same thought is involved in the title Diamond-heart, given to adepts: as hard and indifferent to one's own sorrows as the diamond is hard and enduring, yet like the diamond reflecting in its facets as in mirrors the sufferings and sorrows of all around.
Also personified as a goddess, the wife of Dharma (divine law) and daughter of Daksha.

Tocharia -A people who lived in the Tarim basin of current day China, and who spoke a Indo European language

Trijya is the Sine of an angle of 90^o. It is so called because the angles in the Indic system are measured as multiples of the Rāśi. A Rāśi connotes 30^o. Thus 3 Raśis constitute 90^o. The word is a short form for Trirāśijya. It is equal to the radius. A Trijya thus is also the radius, e.g. 3438 kalā (arc minute) or 1 radian

Tropical Year (Solar year) – the time it takes for the Sun to return to an equinox (365.2421898148 days, or **365^d 5^h, 48^m 45.2^s**. This is also the year where the seasons occur at the same date every year, unlike the Lunar year. The Gregorian Calendar in worldwide use today is based on the Tropical Year.

U

Udaya – Heliacal rising, udayajya

Universal Time (UT) has replaced Mean Solar Time due to a recognition of the non-uniform rotation rate of the earth.
Upamāna – comparison to use in an analogy, simile
Upanishads - of the one hundred and eight extant Upanishads sixteen were recognized by adi Sankara as authentic and authoritative. In his commentary on the Vedanta aphorisms he included quotations from six. On the other ten he wrote elaborate commentaries. It is these ten which have come to be regarded as the principal Upanishads: Isa, Kena, Katha, Prasna, Mundaka, Mandukya, Chandogya, Bṛhadāranyaka, Aitareya, and Taittiriyā.
Upapatti – उपपत्ति, Proof, Demonstration, Rationale, syn. युक्ति, Yukti (see Rationalism)
Urheimat - A postulate that the Proto Indo European people (another postulate) originally lived in a common homeland or Urheimat at some distant past. While this is a very beguiling assumption, there is absolutely no evidence in Archaeology of such a Urheimat. It is purely a hypothetical construct only of academic interest. See the translations of the passages from the Ṛg quoted in the section on AIT, in the context of the discussion on the debate of the origin of the Vedic people.
Utilitarianism – In ethics , a consequentialist system in which actions are judged right or wrong merely by measuring the extent to which they increase or decrease human well being or utility; utility is classically interpreted as human pleasure.
Utkramana, Utkramjya, उत्क्रमज्य - the Versine θ =(1- cos θ)also referred to as sara in Jaina literature . It signifies the maximum perpendicular distance from the apex of the arc to the middle of the chord.

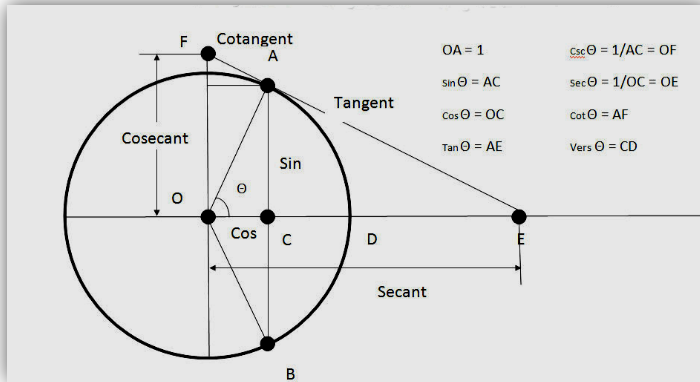


FIGURE 16 JYA AND UTKRAMJYA THE GEOMETRY OF TRIGONOMETRY

Uttarāyana - (**उत्तरायन**) The Sun's northward journey, as viewed from the earth) from winter solstice (shortest daylight hours) to summer solstice (the longest day in the calendar). The period from July 14 to January 14 is known is Dakṣiṇāyana (दक्षिणायन). The name **Uttarāyana** comes from joining two different Sanskrit words "Uttar" (North) and "ayan" (movement towards). Uttarāyana is the day when the Sun starts to travel towards north as a sign of coming summer. People from all age groups, come to the roof of their houses and apartments to fly kites in celebration of the festival. The starting of Uttarāyana is celebrated as Makara Saṃkrāṇti throughout India. There is a reason why Makara Saṃkrāṇti which occurs 25 days after the Solstice is celebrated as the start of Uttarāyana. The answer lies in the fact that, the precession of the equinoxes (and the solstices) has changed the date of the solstice from January 15 to December 22. This in fact tells us that the date when this festival was

delineated was about (24*71.6) = 1718 years ago or 291 CE. Obviously, the winter solstice no longer occurs during Makara Saṃkrāṇti.

Utsarpiṇī is the ascending phase of the non Vedic interpretation of a Mahāyuga, comprising of Kali, Dwapara, Treta and Satya or Krita Yuga. According to such a reckoning we are now in Treta Yuga, in the Utsarpiṇī phase. (See also Avasarpiṇī).999

V

Vaisya - One who benefits humanity by his efforts and specialization in trade, commerce, and agriculture. The commercial sector of society.

Vajra, the shining weapon of Indra

Varāhamihīra was an astronomer and mathematician who contributed much to Indian astronomy. His *Pañchsiddhāntikā* is a treatise and compendium drawing from several knowledge systems. He is also the author of Brihat Saṃhitā. V gives a lucid explanation of Solar and Lunar Eclipses.

Varna letter sounds

Varna asrama dharma - The system, namely Guṇa Varna Vyavastha that produced the Varnāshrama Dharma was conscious of the fact that this was the world's early attempt at a meritocracy. That the system was eminently successful in its own way , I have no doubt because the resulting civilization flourished for well over 5 millennia, until its very foundations were attacked from both within and without by Barbarians, whose notion of entertainment was to build a pyramid of skulls, in order to terrorize the local population to capitulate. The current system in place after the colonial power was done reinventing and reshaping it to its own specifications, and which goes by the name Caste, is so utterly different in all significant ways that we can safely say it has little to do with the Hindu faith or Hindu traditions such as the Guṇa Varna Vyavastha.

Varuna one of the early Vedic deities, literally all-encompassing, precursor of the Hellenic Uranus.

Vākya a sentence

Vedāńga — From Veda and ańga, limb; hence, literally, 'the limb of (the body of) the Veda' — is the name of six Sanskrit works, the object of which is to teach how to read and understand the Vedic texts correctly, and how to apply them appropriately for sacrificial purposes. Whether the number of these works was originally the same as it now is, and already was at the time of the Upanishads, may be doubtful. Tradition mentions the following Vedāńga:

1. **Siksha**, or the science of proper pronunciation. It is represented by a short treatise of 30, or, in another Recension, of 59 verses, which explains the nature of letters, accent, and pronunciation, and is ascribed to *Pāṇiniṇ* ;

2. **Chandas**, or (a work on) metre, which is ascribed to Pingala;

3. **Vyākarana**, or grammar, by which native authorities understand the celebrated work of *Pāṇini* ; but never those short books, especially concerned in Vedic peculiarities, called Pratisakhyas, the existing representatives of which, in all probability, are posterior to Pāṇini ; 4. **Nirukta**; Etymology

5. **Jyotiṣa**, or astronomy. 'Its chief object is to convey such knowledge of the heavenly bodies as is necessary for fixing the days and hours of the Vedic sacrifices;'

6. **Kalpa,** or works on the Vedic ceremonial, which systematize the ritual taught by the Brāhmaṇa portion of the Veda, omitting, however, all legendary or mystical detail. They are composed in the Sūtra style. The Kalpa, or Srauta Sūtras belonging to the RV are the Aśvalāyana, Sankhyayana, and Saunaka Sūtras ; those relating to the Somaveda, the Maśaka, Latyayana, and Drahyqayana Sūtras ; those of the Black Yajur- Veda, the Āpastamba, Baudhāyana, Saty Āṣāḍhā, Hirariyakesin, Mādhava Bharadvaja, Vākuna, Vaikhanasa, LaugahsJii, Maitra, Katha, and Vrddha Sūtras. The White Yajurveda has only one Kalpa, or Srauta Sūtras connected with it, the Kātyāyana Sūtra, and the Atharva Veda likewise only one,

the Kusika Sūtra. At a later period, these works were supplemented by a similar class of works, which, however, merely describe the domestic ceremonies, namely the marriage rite, the rites to be performed at the conception of a child, at various periods before his birth, at the time of his birth, the ceremony of naming the child, of carrying him out to see the sun, of feeding him, of cutting his hair, and lastly, of investing him as a student, and handing him to a guru, under whose care he is to study the sacred writings. Works of this kind are called Grihya-Sūtras (from griha, house), and to these, again, were added the Samayacharika-Sūtras (from samayachara, conventional practice), which treat of customs sanctioned by the practice of pious men, but not enjoined or expressly stated in the Grihya-Sūtras. The two last classes of Sūtras, which are not comprised amongst the Kalpa works, then grew into the Dharma- sastras, or law-books, of which that of Manu is the chief representative.

Vedāṅga Jyotiṣa (VJ) , वेदान्ग ज्योतिष the earliest codified texts of ancient India, and consists of the Ṛg Jyotiṣa ,(RJ) the Atharva Jyotiṣa(AJ) and the Yajusha Jyotiṣa(YJ) . The RJ consists of 36 verses and the YJ consists of 44 verses and the authorship of these two is ascribed to Lagadha.

In Chapter III we have established a terminus ante quem date of 1365 BCE form several markers mentioned in Table 1 in Chapter III and in Chapter VII. There are at least 2 books available on the VJ with an English translation, one by Kuppannna Sastry, and the other by Suresh Chandra Misra. Both are listed in Appendix I.

Vedic civilization - the civilization of the people who composed the Vedas and the vast literature of cosmic proportions associated with the Sanātana Dharma.

Vedics or the Vedic people - the people who composed the Vedas and their Universe of allies and adversaries

Vedic Sarasvati River - The Sarasvati River is mentioned in several verses in the Ṛg at least 50 times as a river flowing from the mountains to the sea. Satellite data has shown evidence of a dried up river bed. Some examples of these quotations are given in the AIT page, http://www.indicethos.org/AIT/. All the AIT and their progeny ignore this significant fact. It is as if the relevance of the reference to the Sarasvati is of no significance at all and if they do deign to acknowledge the reference to the Sarasvati they claim it is a small stream in Afghanistan that never reaches the sea. Reminds one of Oliver Goldsmiths Village Schoolmaster, 'where even though vanquished he could argue still.'

Vernal Equinox - see equinox

Vikalpa – a linguistic construct

Vikshepa, kshepa - Polar latitude, the angle between the ecliptic and the position of the star, measured in the plane of the same great circle as the declination. Note that this is not the same as Celestial latitude or ecliptic latitude

Viṣṇu, विष्णु sustainer of the Universe, whose Avatars came down to earth from time to time to reestablish order in the universe. The Srimad Bhāgvatam is a chronicle of the avatars of

Višuva -spring equinox

Višuvant - summer solstice

Višuvat, **विशुवत** Equator

Višuva Vṛtta – Celestial Equator

Vivāha विवाह marriage ceremony

Vritra – a Vedic demon representing darkness, drought

Vṛtta- Circle

Vṛtti – a commentary

Vyākaraṇa – grammar, the grammar school, one of the traditional schools of Indian philosophy dealing with language and linguistics

Vyāsārdha – व्यासार्ध semi-diameter

W

Y

Yājnavalkya Sage (याज्ञवल्क्य) of Mithila advanced a 95-year cycle to synchronize the motions of the sun and the moon. He is also credited with the authorship of the Ṡatapatha Brāhmaṇa, in which the references to the motions of the Sun and the Moon are found. A date of 3200 BC is sometimes suggested by the astronomical evidence within the Ṡatapatha Brāhmaṇa, while some Western scholars dispute not only the chronology but also his historicity. We have listed him amongst the Indian savants who laid the foundations of Mathematical Astronomy in Ancient India.

Yajur Veda, one of the 4 extant collections of hymns from the ancient era. There are 2 recensions, the Ṡukla Yajurveda and the Kṛṣṇa Yajur Veda

Yamyottara vṛtta Meridian

Yativṛṣabha **Prākrit, Jadivasaha,** *Flourished* **6th century**

Little is known about Yativṛṣabha. He was a Jain monk who studied under Ārya Maṅkṣu and Nāgahastin. He composed, along with other traditional Jain works, the Tiloyapaṇṇattī (in Sanskrit, Trilokaprajñāpati or Knowledge on the three worlds), a work on Jain cosmography. This work describes the construction of the Universe expressed in specific numbers; for example, the diameter of the circular Jambu continent, upon which India is located, is 100,000 yojanas and its circumference is 316,227 yojanas, 3 kroṡas, 128 daṇḍas, 13 aṅgulas, 5 yavas, 1 yūkā, 1 ṛikṣā, 6 karmabhūmivālagras, 7 madhyabhogabhūmivālagras, 5 uttamabhogabhūmivālagras, 1 rathareṇu, 3 trasareṇus, 2 sannāsannas, and 3 avasannāsannas, plus a remainder of 23213/105409. Yativṛṣabha also gives formulas for computing the circumference (C) and the area (A) of a circle having a diameter of d: (area of a circle is equal to the product of half the circumference and the radius. This relation was known to Āryabhaţa,

$$C = \sqrt{10d^2}, \quad A = C\frac{d}{4}$$

Stated alternatively, the problem of finding the side of a square equal in area to that of a circle of unit radius is tantamount to finding the value of $\sqrt{\pi}$. The squaring of the circle is a classical problem in antiquity

Yogasastra, योगशास्त्र The means to attain Moksha or Self Realization, knowledge of Metaphysical aspects of the human consciousness

Yogatārā- Junction star

Yuezhi - the Chinese name for the Kushanas who invaded India. The conventional date for this invasion is at the beginning of the Christian era, but we believe the date is much earlier.

Yukti, युक्ति see Upapatti

Yuga, युग An era of the world. An age of the world, an epoch. Each of these ages is preceded by a period called its Sandhya or twilight, and is followed by another period of equal length called Sandhyansa, 'portion of twilight,' each being equal to one-tenth of the Yuga. The Yugas are four in number, and their duration was defined in terms of years.

At some point in time between the time the Adi Parva and the Harivamsa of the MBH were composed, the ancients postulated that a year of the gods is equal to 360 years of men, which was tatamount to assuming that every day in the Divyabda was equal to 1 year as it was hitherto defined:

4800 x 360 = 1,728,000
3600 x 360 = 1,296,000
2400 x 360 = 864,000

1200 x 360 = 432,000
Total: 4,320,000

1. Krita or Satya	4,000	3. Dvāpara Yuga	2,000
Sandhya	400	**Sandhya**	200
Sandhyansa	400	**Sandhyansa**	200
Total	4,800	**Total**	2,400
2. Treta	3,000	**4. Kali**	1,000
Sandhya	300	**Sandhya**	100
Sandhyansa	300	**Sandhyansa**	100
Total	3,600	**Total**	**1,200**
Mahāyuga	12,000		

FIGURE 17 THE YUGA SYSTEM

Years, forming the period called a Mahāyuga. Two thousand Mahā-yugas or 8,640,000,000 years make a Kalpa or night and a day of Brahma.This elaborate and practically boundless system of chronology was invented between the age of the Ṛg-veda and that of the Mahābhārata. No traces of it are to be found in the hymns of the RV, but it was fully established in the days of the great epic.

Yuga bhagana **– the** number of times that a planet completes its orbit during a Chaturyuga

Zenith- The point directly overhead, which has an altitude of 90 degrees, used in the Horizon coordinate system, azimuth, altitude.

Zero, Śūnya, Discovery and Use of Zero207

In Gayatri chandas, one pada has six letters. When this number is made half, it becomes three (i.e. the pada can be divided into two). Remove one from three and make it half to get one. Remove one from it, thus gets the zero (Śūnya)298. 200 BCE is the date when it was committed to script. Generally there are 2 dates associated with any ancient Indic literature, one associated with the Srautic parampara (oral tradition), and one associated with the likhita parampara (scriptural tradition).

Calculations With Zero[299] Vikāramāyānthi dhanarunakhāni Na Śūnya samyoga viyogathasthu soonyāddhi suddham swamrunam kshayam swam vadhādinā kham khaharam vibhakthā: Nothing happens (to the number) when a positive or negative number is added with 0. When +ve and -ve numbers are subtracted from 0, the +ve number becomes negative and -ve number becomes +ve. When multiplied with 0, the values of both +ve and -ve numbers become 0, when divided by 0; it becomes infinity (khahara). Śrīpati in Siddhānta Śekhara **1039 CE**

Yathā ekarekhā sathasthāne satham daṣasthane daṣaiam chaikasthāne yathā cha ekathvepi sthree mathā cha uchyathe duhithā svasā cha ithi

In the unit place the digit has the same value, in 10th place, 10 times the value and in 100th places 100 times the value, is given.

[298] *Pingalacharya in Chandas Sastra*
[299] *http://shantansblog.com/great-indian-ancient-discovery-and-use-of-zero-by-hindu-scholars-before-200-b-c/*

ZODIAC, THE SIGNIFICANCE OF THE ZODIAC AND ZODIACAL SIGNS.

The Zodiac is a band of about 8.5^o centered in the Ecliptic, called by the Greeks the Kyklos Zodiakos (the circle of the beasts). Zodiacal constellations were discovered in almost all civilizations that were recognized as marking in a general way the path of the Sun. The Ancient Indic called them Rāŝi. In Modern astronomy they are also synonymous with a 30^o segment in the sky that bears the same name as the constellation that is the main inhabitor of that sector particular segment.

APPENDIX B MAPS

FIGURE 1 MAP OF ANCIENT INDIA

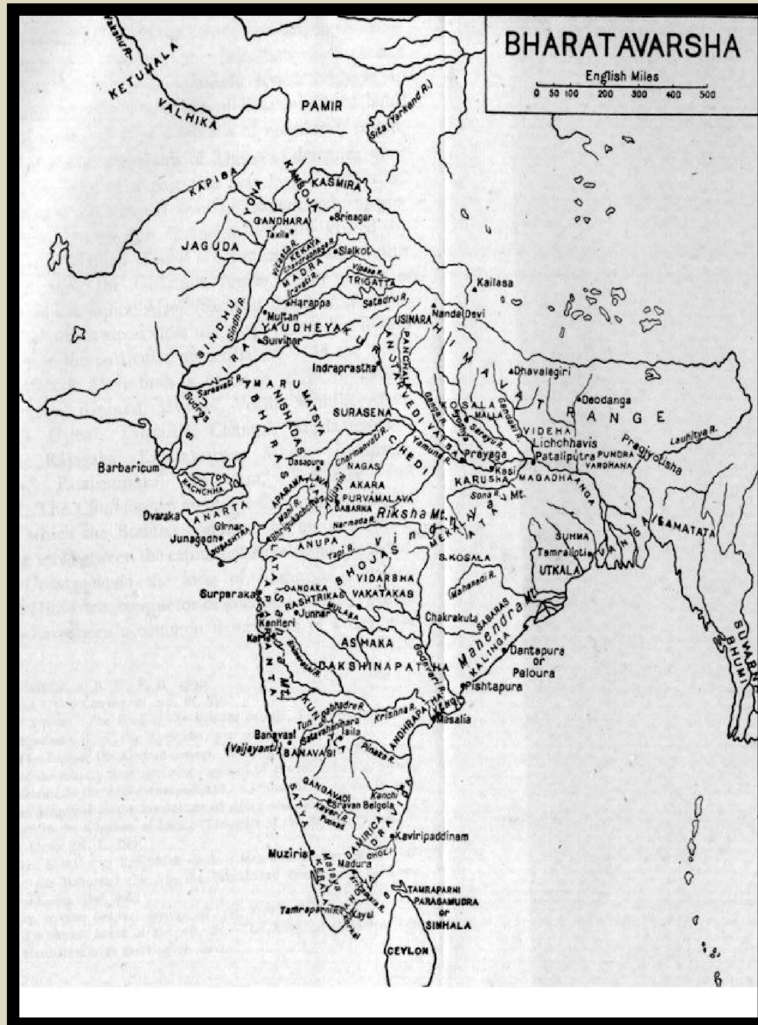


FIGURE 2 THIS MAP SHOWS THE NEWER SITES SUCH AS DHOLAVIRA, LOTHAL, RAKHIGARHI, AND KALIBANGAN

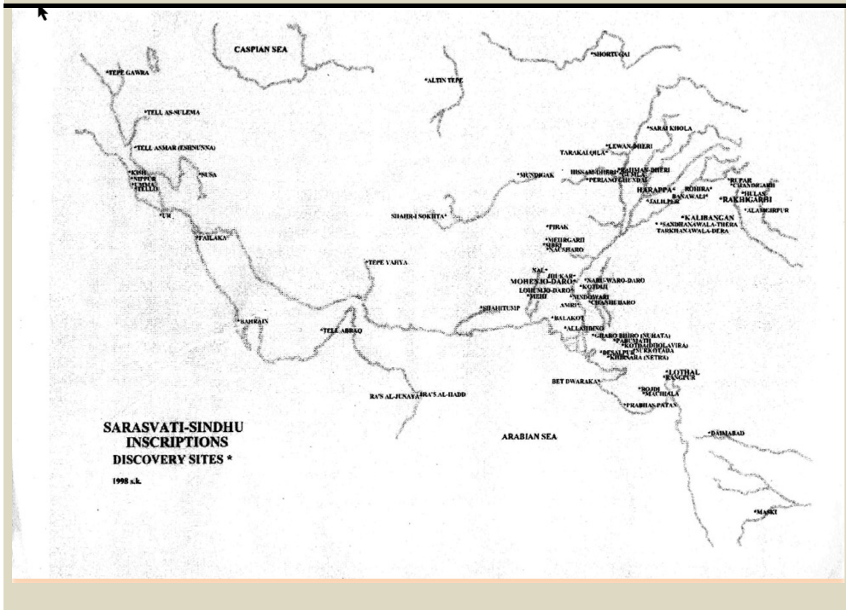


FIGURE 3 EARLY HISTORICAL SITES MAPPED BY THE ARCHAEOLOGICAL SURVEY OF INDIA

FIGURE 4 THE MAP OF THE REPUBLICAN ERA OF INDIA

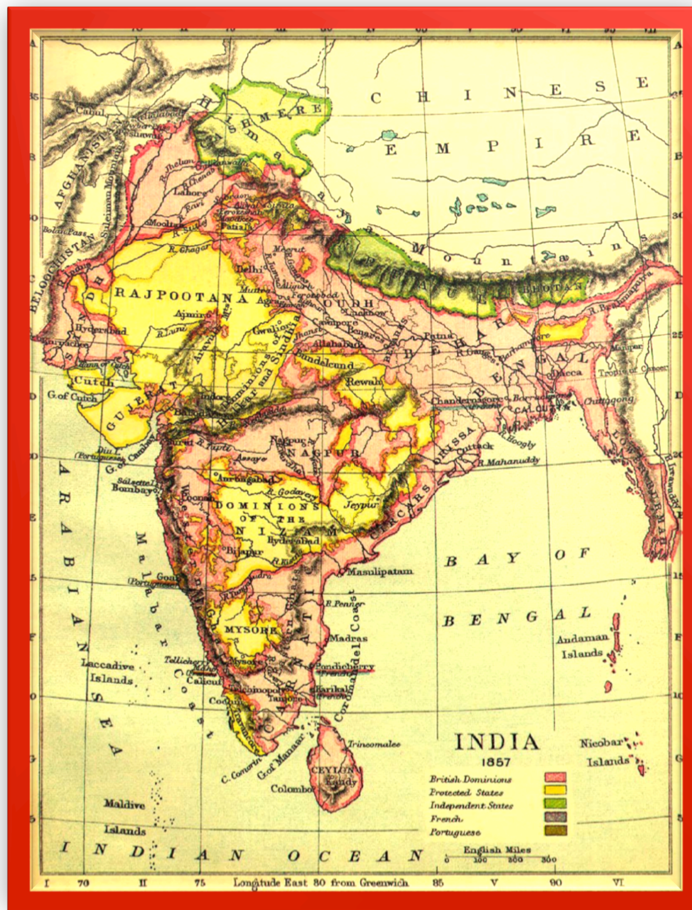
Modern India with some places of historical interest

KEY
★ Country capital
■ State capital
● City

FIGURE 5 RELIEF MAPS OF ISLANDS OF THE COAST OF PRESENT DAY TURKEY WHERE MOST OF THE EARLY GREEK ADVANCEMENTS IN MATHEMATICS TOOK PLACE (YTIME LIFE BSD)



FIGURE 6 POLITICAL MAP OF INDIA 1857, SHOWING AREAS OF BRITISH CONTROL

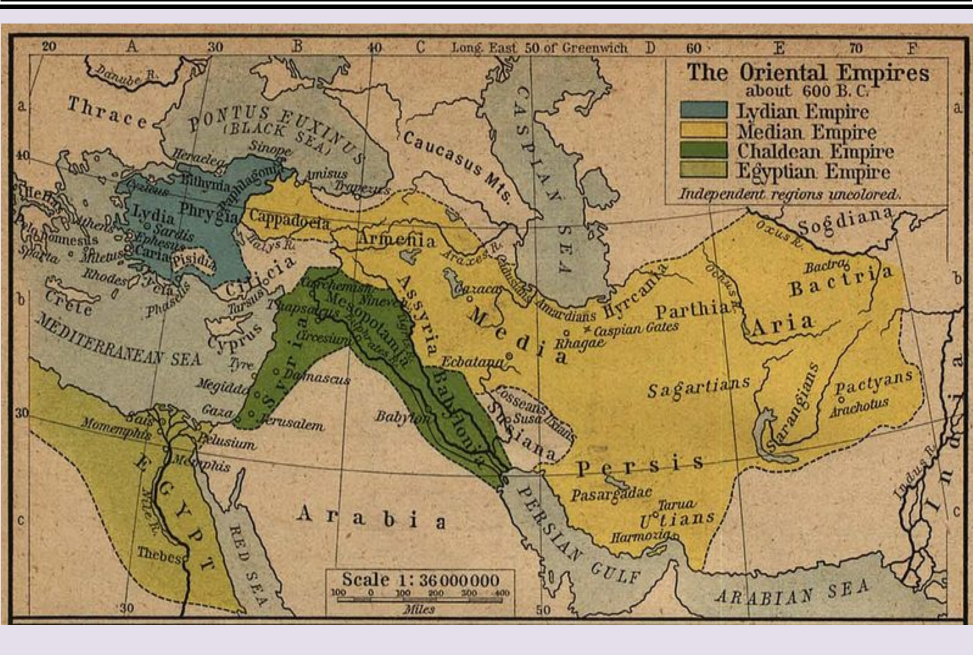


A Chakravartin (possibly one of the Andhra Sātavāhana Kings) 1st century BC/CE. Andhra Pradesh, Amarāvati. (Found at Vemavaram) Preserved at Musee Guimet. Slab from the casing of a Stupa, marble limestone.
870 × 1,057 pixels, file size: 933 KB,



FIGURE 7 LE SOUVERAIN UNIVERSELL, CHAKRAVARTIN

FIGURE 8 THE EMPIRES OF WEST ASIA CA 600 BCE



APPENDIX C
SANSKRIT ALPHABET AND PRONOUNCIATION

संस्कृतम् SAṂSKṚTAM

Sanskrit is the classical language of India and the liturgical language of Hinduism, Buddhism, and Jainism. It was spoken in a substantial portion of the Asian land mass from Central Asia to Indonesia and from Iran to current day Vietnam. It is also one of the 22 official languages of modern India. It is language used in conversation by at least 10 million Indians today, and equals roughly the English speaking population of India. A far higher number are fairly literate in the language (roughly 50 million). The reality is that Sanskrit is hardly a dead language. I am confident that the proportion of Sanskrit speakers in India is greater than the proportion of Latin speakers in Europe and America and while I concede that is not a high enough bar to be significant criterion, it places the whole issue into an appropriate perspective.

The name Saṃskṛtam means "refined", "consecrated" and "sanctified". There are substantial misconceptions regarding the place of Sanskrit at the Indian National level, even amongst those who consider themselves Sanskrit scholars in the West. The failing of many modern day historiographers is that they see the past colored by the conditions prevailing today. The Saṃskṛtic civilization which was pervasive throughout large parts of Asia, so much so that, the signs of such a civilization are quite apparent even today. And yet we hear Indologists especially from the west sneer at this language and call it a dead language. The reality is far different. There is in reality a symbiotic relationship between Samskṛtam and the regional languages which nourishes both. The Sanskritic culture, of which the astronomy is a key part, pervades a large part of Asia from Persia in the west, Mongolia on the north and Indonesia in the South. Vedic Sanskrit, the pre-Classical form of the language of the Vedic religion, is the earliest attested member of the Indo-European language family. The oldest known text in Sanskrit, the *Rigveda*, a collection of over a thousand Hindu hymns, composed during the 7^{th} to 4^{th} millennium BC. Today Sanskrit is being revived as an everyday spoken language in the village of Mattur near Shimoga in Karnataka. A modern form of Sanskrit is one of the 17 official home languages in India. This very cursory glance the alphabet of which we have provided here for the sake of convenience is certainly woefully inadequate in order to attain even a minimum level of proficiency for appreciating the Sanskrit slokas in this book but at least you will know what the Sanskritic script looks like. Since the late 19th century, Sanskrit has been written mostly with the Devanāgarī alphabet. However it has also been written with all of the other alphabets of India, except Gurumukhi and Tamil, and the Grantha, Sharda and Siddham alphabets are used only for Sanskrit.
Since the late 18th century, Sanskrit has also been written with the Latin alphabet. The most commonly used system is the International Alphabet of Sanskrit Transliteration (IAST), which has been the standard for academic work since 1912.

DEVANĀGARĪ ALPHABET FOR SANSKRIT
VOWELS AND VOWEL DIACRITICS

अ	आ	इ	ई	उ	ऊ	ऋ	ॠ	ए	ऐ	ओ	औ	अं	अँ	अः	ऌ	ॡ
a	ā	i	ī	u	ū	ṛ	ṝ	e	ai	o	au	aṅ	aṃ	aḥ	ḷ	ḹ
[ʌ]	[aː]	[i]	[iː]	[u]	[uː]	[r̩]	[r̩ː]	[eː]	[aːi̯]	[o]	[aːu̯]	[aŋ]	[ə̃]	[əh]	[l̩]	[l̩ː]
प	पा	पि	पी	पु	पू	पृ	पॄ	पे	पै	पो	पौ	पं	पाँ	पः	पॢ	पॣ
pa	pā	pi	pī	pu	pū	pṛ	pṝ	pe	pai	po	pau	paṅ	paṃ	paḥ	pḷ	pḹ

CONSONANTS

We have made some changes to this cha stands for च, chha stands for छ

क	ka	[kʌ]	ख	kha	[kʰʌ]	ग	ga	[gʌ]	घ	gha	[gʱʌ]	ङ	ṅa	[ŋʌ]
च	ca	[cʌ]	छ	cha	[cʰʌ]	ज	ja	[ɟʌ]	झ	jha	[ɟʱʌ]	ञ	ña	[ɲʌ]
ट	ṭa	[ʈʌ]	ठ	ṭha	[ʈʰʌ]	ड	ḍa	[ɖʌ]	ढ	ḍha	[ɖʱʌ]	ण	ṇa	[ɳʌ]
त	ta	[tʌ]	थ	tha	[tʰʌ]	द	da	[dʌ]	ध	dha	[dʱʌ]	न	na	[nʌ]
प	pa	[pʌ]	फ	pha	[pʰʌ]	ब	ba	[ʋʌ]	भ	bha	[bʱʌ]	म	ma	[mʌ]
य	ya	[jʌ]	र	ra	[rʌ]	ल	la	[lʌ]	व	va	[ʋʌ]			
श	śa	[ɕʌ]	ष	ṣa	[ʂʌ]	स	sa	[sʌ]						
ह	ha	[ɦʌ]	ळ	ḷa	[ɭʌ]									

TABLE 1 TRANSLITERATION AND DIACRITICALS ENCODED IN UNICODE HEX

CONJUNCT CONSONANTS

There are about a thousand conjunct consonants, most of which combine two or three consonants. There are also some with four-consonant conjuncts and at least one well-known conjunct with five consonants. You can find a full list of conjunct consonants used for Sanskrit at: http://sanskrit.gde.to/learning_tutorial_wikner/P058.html

क्क	क्ख	क्च	क्ण	क्त	क्त्य	क्त्र	क्त्र्य	क्त्व	क्न	क्न्य	क्म
kka	kkha	kca	kṇa	kta	ktya	ktra	ktrya	ktva	kna	knya	kma
क्य	क्र	क्र्य	क्ल	क्व	क्व्य	क्ष	क्ष्म	क्ष्य	क्ष्व	ख्य	ख्र
kya	kra	krya	kla	kva	kvya	kṣa	kṣma	kṣya	kṣva	khya	khra
ग्य	ग्र	ग्र्य	घ्न	घ्न्य	घ्म	घ्य	घ्र	ङ्क	ङ्क्त	ङ्क्त्य	ङ्क्य
gya	gra	grya	ghna	ghnya	ghma	ghya	ghra	ṅka	ṅkta	ṅktya	ṅkya
ङ्क्ष	ङ्क्ष्व	ङ्ख	ङ्ख्य	ङ्ग	ङ्ग्य	ङ्घ	ङ्घ्य	ङ्घ्र	ङ्ङ	ङ्न	ङ्म
ṅkṣa	ṅkṣva	ṅkha	ṅkhya	ṅga	ṅgya	ṅgha	ṅghya	ṅghra	ṅṅa	ṅna	ṅma
ङ्य	च्च	च्छ	च्छ्र	च्ञ	च्म	च्य	छ्य	छ्र	ज्ज	ज्झ	ज्ञ
ṅya	cca	ccha	cchra	cña	cma	cya	chya	chra	jja	jjha	jña
ज्ञ्य	ज्म	ज्य	ज्र	ज्व	ञ्च	ञ्च्म	ञ्च्य	ञ्छ	ञ्ज	ञ्ज्य	ट्ट
jñya	jma	jya	jra	jva	ñca	ñcma	ñcya	ñcha	ñja	ñjya	ṭṭa

Letter	*Unicode*	*Description*	*Sanskrit*
Ā	*0101*	*Latin small letter a with macron*	*आ*
Ā	*0100*	*Latin capital letter with macron*	*आ*
Ī	*012A*	*Latin capital letter I with Macron*	*ई*
ī	*012B*	*Latin small letter I with Macron*	*ई*
ĥ	*0125*	*Latin small letter h with circumflex*	*visarga*
Ĥ	*0124*	*Latin capital letter h with circumflex*	
ḥ		***Visarga*** *(visarga) is a Sanskrit word meaning "sending forth, discharge". In Sanskrit phonology, visarga (also called, equivalently, visarjanīya by earlier grammarians) is the name of a phone, [h], written as IAST <ḥ>, Harvard-Kyoto <H>, Devanagari ‹ः›.*	
Ḍ	*1E0C*	*Latin capital letter D dot below*	*As in ढ*
ḍ	*1E0D*	*Latin small letter d with dot below*	
Ḹ	*1E38*	*Latin capital letter L with dot below and macron above*	*ॡ*
ḹ	*1E39*	*Latin small letter L with dot below and macron above*	
Ṃ	*1E42*	*Latin capital letter M with dot below -chandrabindu*	*As in अँ*
ṃ	*1E43*	*Latin small letter m with dot below*	
ṇ	*0146*	*Latin small letter n with dot below*	
Ṇ	*0145*	*Latin capital letter n with dot below*	*ण*
Ṅ	*0143*	*Latin capital letter n with acute*	*As in ङ*
ṅ	*0144*	*Latin small letter n with acute*	*ङ*
Ṛ	*0156*	*Latin capital letter R with dot below*	*ऋ*
ṛ	*0157*	*Latin small letter r with dot below*	*ऋ*
ṣ	*015F*	*Latin small letter s with dot below*	*ष*
Ṣ	*015E*	*Latin capital letter S with dot below*	
ṡ	*015B*	*Latin small letter s with dot above*	*श*
Ṡ	*015A*	*Latin capital letter S with dot above*	*श*
Ṭ	*0162*	*Latin capital letter with dot below*	
ṭ	*0163*	*Latin small letter t with dot below*	*As in ट*
ū	*016B*	*Unicode Character 'latin small letter u with macron'*	*As in Sūrya*
Ū	*016A*	*Unicode Character 'latin capital letter u with macron'*	

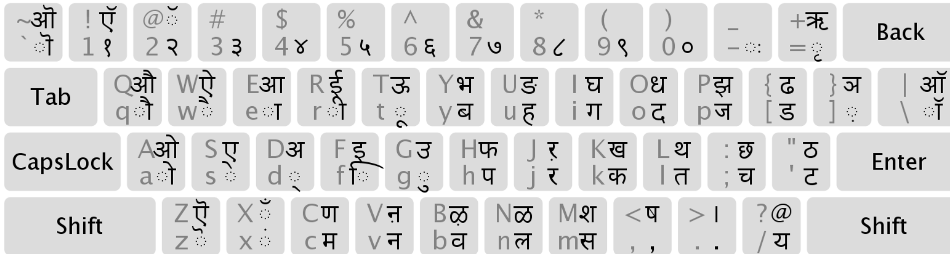
NUMERALS

०	१	२	३	४	५	६	७	८	९	१०
शून्य	एक	द्वि	त्रि	चतुर्	पञ्चन्	षष्	सप्तन्	अष्टन्	नवन्	दशन्
śūnya	eka	dvi	tri	catur	pañcan	ṣaṣ	saptan	aṣṭan	navan	daśan
0	1	2	3	4	5	6	7	8	9	10

SAMPLE TEXT IN SANSKRIT

सर्वे मानवाः स्वतन्त्राः समुत्पन्नाः वर्तन्ते अपि च, गौरवदृशा अधिकारदृशा
च समानाः एव वर्तन्ते। एते सर्वे चेतना-तर्क-शक्तिभ्यां सुसम्पन्नाः सन्ति।
अपि च, सर्वेऽपि बन्धुत्व-भावनया परस्परं व्यवहरन्तु।

Transliteration
Sarvē mānavāḥ svatantratāḥ samutpannāḥ vartantē api ca, gauravadr̥śā adhikāradr̥śā ca samānāḥ ēva vartantē. Ētē sarvē cētanā-tarka-śaktibhyāṁ susampannāḥ santi. Api ca, sarvē'pi bandhutva-bhāvanayā parasparaṁ vyavahārantu.
Translation
All human beings are born free and equal in dignity and rights. They are endowed with reason and conscience and should act towards one another in a spirit of brotherhood. *(Article 1 of the Universal Declaration of Human Rights)*



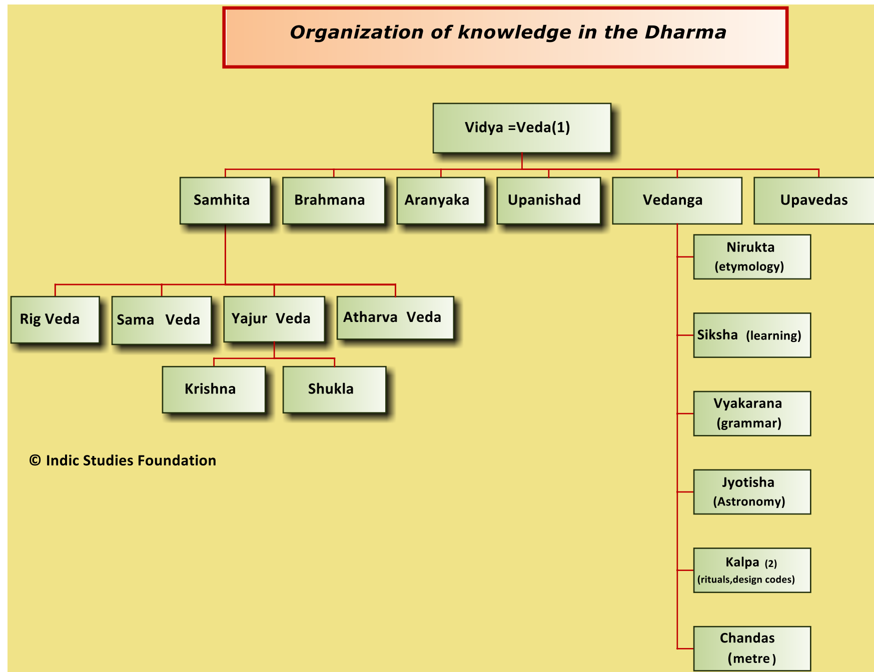
Links - Many more resources are listed in APPENDIX H, I, J and K
Free Devanagari fonts
http://www.kiranfont.com

Information about the Sanskrit language
http://en.wikipedia.org/wiki/Sanskrit
http://www.sanskrit-sanscrito.com.ar
Online Sanskrit lessons
http://acharya.iitm.ac.in/sanskrit/tutor.html
http://ccbs.ntu.edu.tw/DBLM/olcourse/sanskrit.htm
http://www.utexas.edu/cola/centers/lrc/eieol/vedol-0-X.html
http://www.elportaldelaindia.com/El_Portal_de_la_India_Antigua/Sánscrito.html
Sanskrit Academy
http://www.samskrtam.org/
Cologne Digital Sanskrit Lexicon
http://webapps.uni-koeln.de/tamil/
Sanskrit Library - contains digitized Sanskrit texts and various tools to analyze them
http://sanskritlibrary.org/
Samskrita Bharati - an organization established as an experiment in 1981 in Bangalore to bring Sanskrit back into daily life: http://www.samskrita-bharati.org/
American Sanskrit Institute
http://www.americansanskrit.com
Cologne Digital Sanskrit Lexicon
http://webapps.uni-koeln.de/tamil/
Sanskrit Library - contains digitized Sanskrit texts and various tools to analyze them
http://sanskritlibrary.org/
Samskrita Bharati - an organization established as an experiment in 1981 in Bangalore to bring Sanskrit back into daily life: http://www.samskrita-bharati.org/
American Sanskrit Institute
http://www.americansanskrit.com

APPENDIX D
THE VEDIC EPISTEME

Parā-Vidya (Transcendental Sciences) and Aparā Vidya (Sciences of the material world)

FIGURE 1 THE VEDIC EPSTEME – ORGANIZATION OF KNOWLEDGE IN THE VEDA



To those who are relatively unfamiliar with the Hindu Dharma , the vast panoply and canon of Hindu Ṡāstra is both bewildering and overwhelming. Just as there is order in the cosmos, an order that needs effort and diligence to discover and comprehend, so also it is the case with the discovery of the ontology and structure of the Dharma, an effort which I might add is more than rewarding. Ṡāstra is a Sanskrit word used to denote education/knowledge in a general sense. The word is generally used as a suffix in the context of technical or specialized knowledge in a defined area of practice. For example, Astra Ṡāstra means, knowledge about ―Handling of weapons", Astra means weapons, and Ṡāstra, is their knowledge.

The scripture of the Hindu is broadly divided into

Ṡruti (Sanskrit श्रुति) that which is heard and

Smṛti (Sanskrit: स्मृति) that which is remembered.

Ṡruti, the main body of the Hindu canonical scripture, comprises the following (Figure 1):

The Veda, the Sāṃhita Canon (RV, AV, YV, SV)
The Vedic appendices (Āranyaka, Brāhmaṇa, Upanishad
The six Vedāṅgas

There is no simple way to describe the contents of the Veda. The Veda or Vedas–the RV, the SV, the AV, the YV, comprise the Saṃhitās–texts of prayers and hymns, charms, invocations and sacrificial formulae. The RV is an ancient Indian sacred collection of Vedic Sanskrit hymns. It is counted among the four canonical sacred texts (*Śruti*, श्रुति) of Hinduism known as the Vedas. Some of its verses are still recited as Hindu prayers, at weddings and other occasions, putting these among the world's oldest religious texts in continued use.

The **Atharva Veda (AV)** is a sacred text of Hinduism, part of the four books of the Vedas. It derives from the Indo-*Ārya*n name Atharvan, a term which is usually taken to mean a fire priest in Vedic Sanskrit. More specifically, the Atharva Veda was mainly composed by two clans of fire priests known as the Bhrgu (also called Atharvan) and Angirasa. Additionally, it also includes composition of certain other Indo-*Ārya*n clans such as the Kausika, Vaṡiṣṭa, and Kashyapa. Their composition precedes their arrangement into the four Saṃhitās by a long period of aural transmission. The word Veda is derived from the root word Vid or Knowledge and is cognate with the English words wisdom, wit.
One of the Saṃhitās that deals with the lifestyle of the Vedic era is the Yajurveda. In the White (Shukla parampara) the Vājasaneyi Saṃhita[300] mentions leisure time activities amongst other lifestyle choices.

ON THE QUESTION OF THE DISTINCTION BETWEEN ṠRUTI श्रुति, AND SMRITI (स्मृति

On the question of the distinction between Ṡruti श्रुति, and Smṛti (स्मृति) I believe too much is read into such a perceived difference in importance. My interpretation is that at the time of the composition of the Vedas, there was the problem of the episteme becoming extinct due to lack of faithfulness of transmission and lack of understanding of the contents. They used the artifice that it is derived from a higher source. And they developed the Chandas and the Sūtra technology as a mnemonic device. This ensured that the greatest danger to the transmission of this episteme namely that of extinction was no longer a threat. It is ironical that the most accurate preservation of these texts was during the era when they had to rely solely on the Sūtra technology. When once they resorted to the Likhit (script) Parampara and the written word, it became progressively more difficult to maintain the integrity of the texts and protect them. However paradoxically, it is still the case that the task of maintaining integrity of the texts has increased in some respects, because of apathy, destruction by natural and manmade causes, and a whole host of other reasons. But the original Riṣis did their job exceedingly well, as witnessed by the fact that a large portion of the Vedas remains extant even today. All in all the Vedics must be commended that a large portion of the ancient literature has survived. They have fulfilled their obligation to future generations. But care has to be exercised to ensure that as far as is discernible vulgate texts are used in the process of deciphering the events of this ancient era. It only remains for us to see that the authenticity of the ancient texts is preserved. Manuscript on palm leaves do not last more than a couple of hundred years and it is important that the aural tradition be maintained as the platinum version from which the written versions are regenerated .6333333333333333

THE UPANISHADS

[300] *There are two (nearly identical)* shakhas *or recensions of the Shukla (White) Yajurveda, both known as Vajasaneyi-Saṃhita (VS): Vajasaneyi Madhyandiniya (VSM), originally of Bihar, Vajasaneyi Kanva of originally of Kosala (VSK).*

The Bhagvad Gita (the Song Celestial) is actually a part of the MBH epic (The Great Bharata epic) but by universal consent and acclaim has attained the status of Śruti over time because of the eternal verities that it espouses. The scene develops as a dialogue between Sri Kṛṣṇa (the 7th Avatar of lord Vishnu) and Arjuna, the Pandava prince and is set in the backdrop of the MBH War (The Great Bharata War) which takes place in the battlefield of Kurukshetra not too far from the environs of present day Delhi. The iconic significance of this historic dialogue between the Lord (the manifestation of Brahman) and his disciple (a metaphor for all of humanity) to the Indic throughout the ages till the present day is so immense and so timeless and relevant in its message, that hyperbole would not suffice to describe the same. It remains indeed a stirring call to the observance of Dharma in one's own life. The date for the MBH war remains unsettled to this day but compelling arguments can be made for dating it to the end of Kaliyuga circa 3100 BCE. We will describe some of the methodologies and the results of these attempts later in the FAQ. Smriti comprise the rest of the scriptures. There are eighteen main Smriti, each one named after its principal author;

Manu Smriti, Yājnavalkya Smriti, Parasara Smriti, Vishnu Smriti, Daksha Smriti, Samvarta Smriti, Vyāsa Smriti, Harita, Smriti, Satapata Smriti, Vaśiṣţa Smriti, Yama Smriti, Āpastamba Smriti, Gautama Smriti, Devala Smriti, Sankhya-Likhita Smriti, Usana Smriti, Atri Smriti, Saunaka Smriti.
Incidentally, the number 18 crops up ubiquitously in Vedic literature and Indian astronomy, and have special significance, as do other multiples of 9, such as 27, 108, 360, and 432. They can also be classified according to the following taxonomy:

THE UPA-VEDAS

ArthaVeda (the sciences of Economics, Commerce, Geopolitics, and Sociology).
DhanurVeda (the science of War).
GāndharvaVeda (the science of Music).
Ayurveda (the science of Medicine).

And can be broadly categorized into:

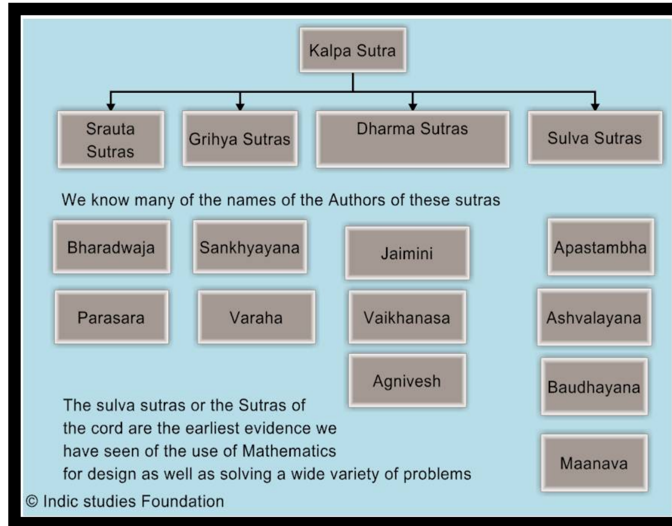
1. **Dharma Śāstra. (the laws)**
2. **Mahākavya (the Epics; they include MBH and the Rāmāyaṇa)**
3. **Purāna (the fables or writings)**
4. **Sūtra (proverbs or aphorisms)**
5. **Āgama आगम (the philosophies; including Mantra, Tantra, and Yantra)**
6. **Dyasana or Darśana (the philosophies; including the Vedanta)**

The Vedāńgas provide the infrastructure and disciplines needed to study the Veda Vyākarana (the Grammar of Language and Sanskrit in particular was first codified by Pāṇini in his Epoch making work, the Ashtadhyāyi. We will have more to say about this extraordinary individual later under the topics of Mathematics and his possible discovery of Zero and the study of Linguistics. Pāṇini was undoubtedly one of the earliest, if not the first among all grammarians in the history of the world).

1. **Jyotiṣa (Astronomy and Astrology)**
2. **Nirukta (Etymology and Linguistics)**

3. **Siksha (Phonetics)**
4. **Chandas (Meter, chanting of poetry)**
5. **Kalpa Sūtra (Ritual procedures)**

FIGURE 2 COMPUTATIONAL SCIENCES IN THE KALPA (SULVA) SŪTRA



To conclude this brief survey of the ancient scriptures, let us remind ourselves that the bulk of the literature has been lost due to a variety of reasons over the millennia that have elapsed since they were first composed.

Then there are the 3 Vedic appendices The Āraṇyakas The Brāhmaṇas and the Upanishads

THE PURĀṆAS

One of the etymologies suggested for the name Purāṇa is Purapi Navaha – meaning "though old, yet ever new". It is an account of the history of Bharat; It is not merely an account of the kings. It is an account of the life of the people and the culture and religion. It contains the origin and history of the entire human race.

The Purāṇas are of the same class as the Itihàsa (the Rāmāyaṇa , MBH, etc.).They have five characteristics (Pancha Lakshana), namely, history, cosmology (with various symbolical illustrations of philosophical principles), secondary creation, genealogy of kings, and of Manvantaras. All the Purāṇas belong to the class of Suhrit-Sammitas, or the Friendly Treatises, while the Vedas are called the *Prabhu-Sāmhita*s or the Commanding Treatises with great authority. They are regarded as being more approachable, than the other Sutra texts which are terse.

Vyāsa is the compiler of the Purāṇas from age to age; and for this age, he is Kṛṣṇa-Dvaipayana, the son of Parasara. The Purāṇas are classified into a *Mahā*–(—great") and an *Upa*–(—lower, additional") corpus.

According to Matsya Purāṇa, they are said to narrate five subjects, **called Pancha Lakshana (—five distinguishing marks"):**

TABLE 1	WHAT SHOULD A PURAṆA COMPRISE OF , PANCHA LAKSHANA OF A PURAṆA
1.	Sarga–The creation of the universe
2.	Pratisarga–Secondary creations, mostly re-creations after dissolution include,
3.	Vamša–Genealogy of gods and sages
4.	Manvantara–The creation of the human race and the first human beings
5.	VamSānucharitam–Dynastic histories
sargascha prathisargascha vamsamanvantharAni cha I VamSānucharitam chaiva Purāṇam panchalakṣanam II सर्गस्च प्रथिसर्गस्च वम्समन्वन्थरानि च । वम्सानुचरितम् चैव पुराणाम् पंचलक्षणं ॥	

Manvantras is the period of Manu's rule consisting of 71 celestial Yugas or 308,448,000 years. The Purāṇas were written to popularize the religion of the Vedas. They contain the essence of the Vedas. The aim of the Purāṇas is to impress on the minds of the masses the teachings of the Vedas and to generate in them devotion to God, through concrete examples, myths, stories, legends, lives of saints, kings and great men, allegories and chronicles of great historical events. The sages made use of these parables to illustrate the eternal principles of religion. The Purāṇas were meant, not only for the scholars, but for the vast majority of the populace who found the Daršanas too abstract and who could not, for whatever reason, study the Vedas.

The Darsanas or schools of philosophy are very abstract. They are meant mainly for those with an introspective temperament. The Purāṇas can be read and appreciated by everybody. Religion is taught in a very easy and interesting way through the Purāṇas. Even to this day, the Purāṇas are popular. The Purāṇas contain the history of remote times. They also give a description of the regions of the universe not visible to the ordinary physical eye. They are very interesting to read and are full of information of all kinds. Children hear the stories from their grandmothers. Pundits and Purohits hold Kathas or religious discourses in temples, on banks of rivers and in other important places. It is the tradition for bards to recite these stories in song and poetry.

There are eighteen main Purāṇas and an equal number of subsidiary Purāṇas or Upa-Purāṇas. The main Purāṇas are: See Table 2.-

SRIMAD BHĀGAVATA PURĀNA

The *Srimad Bhāgavata Purāṇa* chronicles the legends of the various Avatāras of Lord Vishnu. There are ten Avatāras of Vishnu. The aim of every Avatāra is to save the world from some great danger, to destroy the wicked and protect the virtuous. The ten Avatāras are: Matsya (The Fish), Kurma (The

Tortoise), Varāha (The Boar), Narasimha (The Man-Lion), Vāmana (The Dwarf), Parasurama (Rama with the axe, the destroyer of the Kshatriya race), Ramachandra (the hero of the Rāmāyaṇa –the son of Dasaratha, who destroyed Ravana), Sri Kṛṣṇa, the teacher of the Gita, Buddha (the prince-ascetic, founder of Buddhism), and Kalki (the hero riding on a white horse, who is to come at the end of the Kali-Yuga). In short the Bhāgavata Purāṇa is the chronicle of the Indic peoples since the dawn of history ever since the human species evolved into mammals from the oceans and waters of the planet.

TABLE 2 THE MAIN PURAṆAS

Vishnu Purāṇa,	**Mārkandeya Purāṇa,**
Naradīya Purāṇa,	**Linga Purāṇa,**
Garuda (Suparna) Purāṇa,	**Śiva Purāṇa,**
	Skanda Purāṇa

The object of the Matsya Avatāra was to save Vaivasvata Manu from destruction by a deluge. The object of Kurma Avatāra was to enable the world to recover some precious things which were lost in the deluge. The Kurma gave its back for keeping the churning rod when the Gods and the Asuras churned the ocean of milk (Samudra Manthan).

The purpose of Varāha Avatāra was to rescue, from the waters, the earth which had been dragged down by a demon named Hiranyākṣa. The purpose of Narasimha Avatāra, half-lion and half-man, was to free the world from the oppression of Hiranyakasipu, a demon, the father of Bhakta Prahlada. The object of Vāmana Avatāra was to restore the power of the gods which had been eclipsed by the penance and devotion of King Bali. The object of Parasurama Avatāra was to deliver the country from the oppression of the Kshatriya rulers. Parasurama destroyed the Kshatriya race twenty-one times. The object of Rama Avatāra was to destroy the wicked Ravana. The object of Sri Kṛṣṇa Avatāra was to destroy Kamsa and other demons, to deliver His wonderful message of the Gita in the MBH war, and to become the centre of the Bhakti schools of India. The object of Buddha Avatāra was to prohibit animal sacrifices and teach piety. The object of the Kalki Avatāra is the destruction of the wicked and the re-establishment of virtue.

WHAT ARE THE CHARACTERISTICS OF THE PURĀṆAS?

Padma Purāṇa,	**and**
Varāha Purāṇa,	**Agni Purāṇa.**
Brahma Purāṇa,	**Bhaviṣya Purāṇa,**
Brahmānda Purāṇa, **Brahma Vaivarta**	**Vāmana Purāṇa,** **Matsya Purāṇa,**
Purāṇa,	**Kurma Purāṇa**

The Purāṇas are a class of literary texts, all written in Sanskrit verse, whose composition dates from the time of Veda Vyāsa, who lived at the time of the MBH. The Purāṇas are regarded by some as the Veda when studied under a magnifying glass. The word "Purāṇa" means "old" and in fact *Pāṇini* assigns the meaning "complete" (cognate with pūrna). Generally they are considered as following the chronological aftermath of the epics, though sometimes the *MBH*, which is generally classified as a work of *Itihāsa* (history), is also referred to as a Purāṇa. Some Occidental scholars, such as van Buitenen[301], are inclined to view the Purāṇas as beginning around the time that the composition of the MBH came to a close. Certainly, in its final form the *MBH* shows Purāṇic features, and the Harivamsa, which is an appendix to the MBH, where the life of Kṛṣṇa or Hari is treated at some length, has sometimes been seen as a Purāṇa. The special subject of the Purāṇas is the powers and works of the gods, and one ancient Sanskrit lexicographer, Amarāsimha, regarded by some as a Jain , and by others as a Buddhist who was reputed to be a courtier of Vikramāditya, defined a Purāṇa as having five characteristic topics, or "Panchalakṡanam: "

No one Purāṇa can be described as exhibiting in fine (or even coarse) detail all five of these distinguishing traits, but sometimes the *Vishnu Purāṇa* is thought to most closely resemble the traditional definition. Vyāsa composed the Purāṇas in 400, 000 "Grantha". A Grantha is a stanza consisting of 32 syllables. Of these the *Skanda Purāṇa* alone accounts for 100, 000. It is perhaps the world's biggest literary work. The remaining 17 Purāṇas add up to 300, 000 Granthas. Apart from them Vyāsa composed the MBH, which comprised also nearly 100, 000 Granthas.
Each Purāṇa is devoted to a particular deity. There are Saiva, Vaisnava, and Sakta Purāṇas. The 18 Purāṇas: Brahma Purāṇa (Brahma), Padma Purāṇa (Padma), Narada Purāṇa (Naradiya), Markandeya Purāṇa, Visnu Purāṇa (Vaisnava), Siva Purāṇa(Saiva), Bhāgavata Purāṇa, Agni Purāṇa (Agneya), Bhavisya Purāṇa, Brahma-Vaivarta Purāṇa, Linga Purāṇa, Varāha Purāṇa (Varāha), Skanda Maha Purāṇa, Vāmana Purāṇa, Kurma Purāṇa (Kaurma), Matsya Purāṇa (Matsya), Garuda Purāṇa (Garuda) and Brahmanda Purāṇa.

ARE THE PURĀṆAS CREDIBLE AS SOURCES OF HISTORY

My word on this matter may not have much cachè in the Occident, but let us see what Pargiter has to say in Chapter X of AIHT, titled "General credibility of the Purāṇas". Why do we pick Pargiter? It is for the same reasons we mention at the beginning of this paper, namely that he has studied them thoroughly. Few Englishman are adulatory about anything Indian, but he comes close to being as unbiased as an Englishman can be about matters Indian. Then he goes on to say; "The *question naturally arises whether credence can be attached to the foregoing royal genealogies. Kingdoms and dynasties existed, as we know even from the Vedic literature, and their genealogies must have existed and would have been preserved as long as the dynasties endured. It is incredible that the students of ancient traditional lore, who existed continuously as pointed out in Chapter II, discarded or lost these famous genealogies and*

[301] *Van Buitenen 1981 The Bhagavad-Gita in the Mahabharata. Translated by J. A. B. van Buitenen, edited by James L. Fitzgerald. Chicago, 1981*

preserved spurious ones. This does not mean that spurious genealogies were never fabricated, for some were devised as will be noticed; but fictitious pedigrees presuppose genuine pedigrees, and it is absurd to suppose that fiction completely ousted truth: so that, ***if any one maintains that these genealogies are worthless, the burden rests on him to produce, not mere doubts and suppositions, but substantial grounds and reasons for his assertion****. Common sense thus shows that these genealogies cannot be fictitious and the foregoing question are narrowed down to this, whether they can be accepted as substantially trustworthy. Their credibility can be tested in various ways. …*

*These considerations show that the genealogies have strong claims to acceptance. This does not mean that they are complete and altogether accurate, because no human testimony is free from defects and errors; and it has been shown in the preceding pages, and more will appear in the following pages, that there are defects, gaps and errors in them, especially when taken singly, but many of these blemishes can be corrected by collating the various texts, and others can be remedied by statements found elsewhere. Nevertheless, it is quite clear that they are genuine accounts and are substantially trustworthy***.** *They give us history as handed down in tradition by men whose business it was to preserve the past; and they are far superior to historical statements in the Vedic literature, composed by Brāhmaṇas who lacked the historical sense and were little concerned with mundane affairs."*

A common error in perception amongst Indologists of Europe today (who should know better) is that prior to the coming of the British India had no tradition of history and that the real History of India was initially written by the British and that everything prior to the British was fragmentary. The root of this attitude was the work of Hegel and is now commonly referred to as the Hegelian Hypothesis of Indian History, that India was largely a cul de sac and nothing good emanated from India and that the history of India is largely a history of invasions . In reality, the latter day British historians of the colonial era did not add any factual material to that which they found in the Purāṇas. They merely rearranged the chronology, very often based on flimsy grounds, based on little or no evidence. The most vocal proponent of the Hegelian hypothesis in North America today is Michael Witzel who barely conceals his glee when he points out what he regards as the myriad sins of the Hindus.

We quote Witzel "The royal lists rest, as almost everywhere in traditional cultures, on Bārdic traditions. In India, they derive from lists aurally transmitted and constantly reshaped by the suta bards according to local conditions and personal preference. The eager efforts made by many Indian scholars of various backgrounds to rescue these lists as representing actual historical facts therefore are ultimately futile. The only early Purāṇic kings we can substantiate are those listed in the Vedas as these texts, once composed, could no longer be changed."

One can see that Witzel has chosen to deliberately ignore the admonition of Pargiter that the Indologist cannot afford to ignore the Pauranic lists simply because they are inconvenient or that they do not agree with preconceived notions of Indic antiquity and that **the burden rests on him to produce, not mere doubts and suppositions, but substantial grounds and reasons for his assertion.** As for the need of the Puraṇa to be rescued, we are indeed touched by his concern, but he needs to be reminded that the Puraṇa have survived for well over 3 millennia without any help from Witzel and he should consider himself blessed if his works are remembered for the same length of time.

He makes frequent use of the artifice that occidentals fall prey to, namely converting an assumption into a fact, hoping nobody would notice the switch. For instance he continues to use the adjective Bārdic when referring to the Vedic texts. This is an extraordinary assumption that the Occidental makes, namely that the Vedic slokas are the work of relatively unsophisticated bards rather than the highly regarded Sapta Riṣis. In fact it is for this reason that the Sapta Riṣis referred to the Veda as Śruti in that

they were fully cognizant that there would the real danger that the Veda would be misunderstood by those not qualified to interpret these slokas and hence their admonition that until the seeker or student attains a certain degree of proficiency, he or she should accept the Śruti, as that which is heard? In reality "the hymns of the RV Saṃhita "are obscure, mysterious and exhibit a certain degree of artifice"[302] The quote is from DR. B. G. Siddharth, Director of the Birla Planetarium and a distinguished Astrophysicist with impeccable credentials in the international arena.

It is often asserted, especially when the occidental has no further arguments to sustain his claim that we are not mainstream historians and cannot be taken seriously. One does not need to be a poker player to be reminded that such arguments are a definite admission that they do not have anything more of a substantial nature. Further this is an argument that is used as a last resort. When you have no further rational arguments to make, the shift is made to ad hominem attacks.

But such a Hegelian hypothesis that India was constantly invaded is diametrically opposite to the truth. For a very large part of her millennial history, India was never successfully invaded by anybody and the very uniqueness of the Hindu civilization, which is also often remarked by the very same Occidentalist who propounds the Hegelian hypothesis, is a living testament to the autochthonous developments in the subcontinent. Again we quote Megasthenes;

"But what just reliance can we place on the accounts of India from such expeditions as those of Kyros and Semiramis? If Megasthenes concurs in this view, and recommends his readers to put no faith in the ancient history of India; its people, he says, never sent an expedition abroad, nor was their country ever invaded and conquered except by Herakles and Dionysos in old times, and by the Makedonians in our own. Yet Sesostris the Egyptian and Tearkon the Ethiopian advanced as far as Europe. And Nabukodrosor, who is more renowned among the Chaldaeans than even Herakles among the Greeks, carried his arms to the Pillars, which Tearkon also reached, while Sesostris penetrated from Iberia even into Thrace and Pontos. Besides these there was Idanthyrsos the Skythian, who overran Asia as far as Egypt. But not one of these great conquerors approached India, and Semiramis, who meditated its conquest, died before the necessary preparations were undertaken. The Persians indeed summoned the Hydrakai from India to serve as mercenaries, but, they did not lead an army into the country, and only approached its borders when Kyros marched against the Massagetai."[303]

Thus, a Hegelian construction is far from the truth. The British rarely uncovered new facts about the Kings who ruled India; they merely took what was already there in the Purāṇas and repackaged the chronology to suit their own prejudices. The net result of this is that those of us who were born at the time of independence, learnt only the concocted History of the British, and with the divorce of our education system from traditional knowledge systems, we are one of the first generations to be brought up on a false history and without a counterbalancing access to the traditional versions of our history. It is for this reason that those of us who have had a lifelong passion for Indian history, feel that we are on a journey to decipher the true history of India rather than a cosmetic remake of the severely distorted and revised history that the British attempted to foist upon India.

We are often quoted passages from the Purāṇas to indicate that it is not an accurate account. It is nobody's contention that everything is accurate in the Purāṇas. However, the existence of such inaccurate statements does not negate the rest of history as portrayed in the Purāṇas. Furthermore, if we eliminated from consideration, every historical text in the world that had an inaccuracy, we would

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[302] *Siddhartha, BG, The celestial Key to the Vedas", www.Inner traditions.com, 1999*

[303] *http://projectsouthasia.sdstate.edu/docs/history/primarydocs/Foreign_Views/GreekRoman/Megasthenes, BOOK IV.FRAGM. XLVI. Strabo. XV. I 6-8,--pp. 686-688 (Cf. Epitome. 23.)*

hardly have any history worth the name. Most of Herodotus's history is filled with fanciful exaggerations or the product of a fevered imagination (e.g. that the semen of Indians is black in color).That does not necessarily mean that everything that Herodotus wrote is without historical significance or is as indicative of his ignorance as this assertion. Yet, while most Occidentals are quick to forgive Herodotus his lapses, they remain equally adamant that Indic historical accounts such as in the Purāṇas be pristine in their purity and accuracy. Even, if that were so in all likelihood the English would have found fault with it and changed it as they did many parts of Indian History that were correct. For a proper appreciation of the Indic approach to History, one should make a careful study of the paper presented by Prof Shivaji Singh at ICIH 2009. [304]

The remarks by Pargiter are the best we can hope for from an Englishman. But this is enough to proceed with our study. In the Purāṇic and other literature, there is no allusion anywhere to an invasion or inroad into India by foreign peoples up to the time of the Andhra kings; and the only person who bore the name similar to Sandracottus of the Greeks, and who flourished at the time of Alexander, was Chandragupta of the Gupta dynasty, referred to as the Andhra Bhrityas, who established a mighty empire on the ruins of already decayed Andhra dynasty and existing 2811 years after the MBH War, corresponding to 328 BCE. His date is currently placed in the fourth century CE, which obviously does not stand the test of internal and external consistency. It is also interesting to note that the accounts in the life of Sandracottus of the Greeks, and the political and social conditions in India at that time, match those of in the era of Chandragupta of the Gupta dynasty. With this observation, it is therefore the case that the Greek and Purāṇic accounts unanimously agree on the issue of the identity of Chandragupta of Gupta dynasty and Sandracottus.

To provide a complete picture of the Dynastic lists and the names of the individual Kings of the Magadha Empire, we have added the lists until the end of the Gupta Empire in appendix N. According to Purāṇic evidence, there had expired 1500 years after Parikshit, when Mahāpadmananda was coronated. Between Parikshit and the Nandas, there were 3 royal dynasties, namely the Brihadratha, Pradyota, and Sisunaga families.

The ten kings of the Sisunaga dynasty ruled for 360 years, beginning from 1994 BCE. and ending with 1634 BCE At this time, an illegitimate son, Mahāpadma-Nanda, of the last Sisunaga emperor, Mahānandi, ascended the throne of Magadha. The total regnal period of this Nanda dynasty was 100 years. After this, with the assistance of Ārya Chanakya, Chandragupta Maurya ascended the throne of Magadha, and that is in the year 1534 BCE This date can be arrived and confirmed using many independent accounts. The Mauryas ruled for a total of 316 years, and were replaced by the Sungas. The Kanvas who succeeded the Sungas were themselves overthrown by the Andhra, who in turn ruled for a period of 506 years. Then followed the reign of the Sri Guptas for a period of 245 years, also referred to as the (last of the) Golden ages of Bharata. It was Samudragupta of the SriGupta dynasty, who was known as Asokāditya Priyadarshin. Most of the inscriptions of Aṣoka belong to this Gupta emperor and not to the Aṣoka Maurya who came to power 218 years after the Buddha. Narahari Achar of Memphis University has confirmed many of the dates including that of the Buddha, using Planetarium software, the algorithms in which are based on Celestial Mechanics, has established that the Purāṇic dates are correct based on the sky observations that were recorded by the ancients. This must be regarded as an independent verification since the principles of celestial mechanics were unknown to the ancient Indic.

ITIHĀSA

303 Singh, Shivaji, " Contending Paradigms OF Indian History; Did India lack Historical agency, Keynote address published in Souvenir Volume of ICIH2009.

(Epic history or Mahākavya) Rāmāyaṇa , MBH (the Bhagavad Gita is a part of this monumental epic) When one adds up all of the above, it constitutes a substantial corpus of the record of the Indic civilization ever since the mists of time and it can safely be asserted with a great deal of certitude that this is probably the largest body of extant work, assembled by man in the ancient era.

MEANING OF HISTORY & ITIHĀSA

Historians and philosophers have been contemplating the meaning of history since, well, since the beginning of history! A simple definition of history is" remembering the past "or Knowledge of what has happened from the start until the present. It is also the knowledge of the past since record keeping was initiated. The purpose of studying history in school is to teach the student understanding of what has taken place so that we may build upon and understand how a nation functions and how it came to be. We also study the history of other nations and how their histories interact with our history. A greater awareness of history results in a more enlightened and educated citizenry. Knowledge of our past helps us understand the present and prepare for the future. Knowing the history of the world helps the individual respect and appreciates one's own form of government and society as well as become better informed about differences in the Civilizational ethos of other peoples of the world.
"The word *history* comes from Greek *ἱστορία* (*istoria*), from the hypothesized Proto-Indo-European **wid-tor-*, from the root **weid-*, "to know, to see"(this is a hypothesis). This root is also present in the English word *wit*, in the Latin words *vision* and *video*, in the Sanskrit word *Veda*, and *vedati*, as well as others (The asterisk before a word indicates that it is a hypothetical construction, not an attested form). The original meaning of Itihāsa had a more precise sense than the word History. The etymology attested to by *Pāṇini* indicates **itiha** to mean 'thus indeed, in this tradition'. One of the earliest references to Itihāsa in the literature of antiquity is in Chanakya's *Arthaśāstra*. Our investigations lead us to believe that the Maurya Empire for which he was the preceptor began in 1534 BCE.
Thus, History (Itihāsa) in this definition takes on the meaning more akin to the sense of Historiography and is perhaps even more eclectic and appears to indicate a superset of political science and History as we use them today. Which is why we feel vindicated in calling the Conference I organized a conference on Indian History, even though we included sessions on Geopolitics, Strategic Issues, and put an inordinate emphasis on the history of the computational sciences since we seem to ascribe the same broad meaning that Kautilya did 3 millennia ago. In the MBH , which is itself considered Itihāsa, is the following verse in Adi Parva 1.267,268, that knowledge of the Itihāsa and Purāṇa is essential to the proper understanding of the Veda.

पुराणमितिवृत्तमाख्यायिकोदाहरणं धर्मार्थशास्त्रं चेतीतिहासः
Purāṇa (the chronicles of the ancients), Itivṛtta (history), Ākhyāyika (tales), Udāharaṇa (illustrative stories), Dharmaśāstra, (the canon of Righteous conduct), and Arthaśāstra (the science of Government) are known as (comprise the corpus of Itihasa) History.
Kautilya's Arthaśāstra. , Book 1, Chapter 5 *Tathā hi mahābhārate mānaviye cha – itihāsa-purāṇabhyām vedam samupabrmhayet Bibhety alpaśrutād vedo mām ayaṃ pratariṣyati, iti, purāṇāt purāṇām iti cānyatra. Na chavedena vedasya brahmaṇam sambhavati, na y aparipūrṇasya kanaka-valayasya trapuṇā purāṇam yujyate*

तथ् हि महाभारतॆ मनविऎच "इतिहास पुराणाभ्यां वॆथं समुपब्रिंहयॆत्
बिभॆत्य अल्पश्रुताथ वॆथो माम अयं प्रतरिष्यति " इति पूरणात् पुराणाम इति चन्यत्र ।
न च वॆदॆना वॆदस्य भ्रमणम सम्भवति न ए अपरिपूर्नस्य कनक वलयस्य त्रपुणा पुराणमुल्यतॆ ।

This is why the MBH (Adi-Parva 1.267268 ,) and Manu-Saṃhitā state, "One should complement one's understanding of the Vedas with the help of the Itihāsas and the Purāṇas." And elsewhere it is stated, "The Purāṇas are called by that name because they are complete."
Clearly there is an emphasis on the traditions and on the utilitarian aspect of History, embedded in the etymology of Itihāsa. The reason we draw emphasis to the ambiguity in the use of the word History is that, in our usage in this conference, while we adhere to the broader usage of the word History, we have separated the Civilizational aspects in distinct sessions. There is a reason why we bring attention to the definitions of History and Itihāsa. As we have pointed out in the caricaturization of the Indic, there is a widespread misperception. Amongst present day Indics that India does not have a well-defined sense of History. In fact in a paper titled 'Concept of History in Vedic Rituals' presented at the ICIH 2009 in Delhi, the author argues that "The Vedic ritual texts refer to words like Purāṇa, Itihāsa, upakhyàna, etc. Some of these words are used in the sense of `history' in modern Indian languages. It would be anachronistic to interpret these words from the Vedic texts in this modern sense. In this paper an attempt has been made to understand the concept of history in the Vedic ritual texts and their weltanschauung".
The quintessential quote is that of Kalhana in the Rājataraṇgiṇi, who is regarded as modern in Indian parlance.
Chanakya defines Itihāsa, in the context of the syllabus prescribed for training of a Prince, with the following words;

धर्मार्थ काममोक्षाणामुपदेश समान्वितं ।
पुरावृतं कथायुत्तरूपमितिहासं प्रचक्षते ।।
"Dharmārtha-kāma-mokshānām upadesa-samānvitam |
Purā-vṛttam, kathā-yuttarupam Ithihāsah prachakṣate ||"
History will be the narration of events as they happened, in the form of a story, which will be an advice to the reader to be followed in life, to gain the purusārthas namely Kama the satiation of desires through Artha the tool, by following the path of Dharma the human code of conduct to gain Moksha or liberation.

ā This is but a summary of what we believe to be a more rational view contradictory to the situation described above, that by the time of the Brāhmaṇa and Upanishad (which are considered an appendix to the Veda) and certainly by the time the Itihāsa and Purāṇa were written, there was a well-defined sense of history , so much so that the MBH cautions us (as in the quote from the MBH above) that the Veda are afraid of those who would read the Veda without a prior acquaintance of the Itihāsa and Purāṇa. We are also not comfortable with the implication that the Veda is merely a book of ritual. Such a reductionist argument was initiated by the British who for the most part did not understand the contents of the Veda. Max Müller exemplified this ignorance in his estimation of the Veda. Clearly there was sufficient reason for the caution that was expressed in the MBH.

FABLES AND ALLEGORIES

Panchatantra & Popular literature in Prakrit Languages
The Popular literature consists of the works produced in the Prakrit languages, other than Sanskrit, such as Tamil, Telugu, Hindi, Kannada, Bengali, and so on by eminent scholars over a period of more than three thousand years. Included in this category are both the translations from the Sanskrit and also

original works. Since it is not possible to deal with the entire list we are mentioning a few important works.

Tamil is the oldest of the South Indian languages and in terms of antiquity it may be as old as the Sanskrit itself. A lot of devotional literature was composed in Tamil by the Nayanars and Alvars in the early Christian era. The Sangam literature is a true reflection of the greatness of Tamil as an excellent medium of devotional literature.

Any Telugu literature prior to Nannayya Bhattarakudu's Andhra Mahabharatamu (1000 to 1100 CE) is not available, except in royal grants and decrees. So, Nannayya is known as Ādi Kavi (the first poet). The advanced and well-developed language used by Nannayya suggests that this may not be the beginning of Telugu literature. Andhra Mahābhāratamu was later furthered by Tikanna Somayājī (1205-1288), to be finally completed by Yerrapragada (14th century). Nannaya, Tikanna, and Yerrapragada are known as the Kavitraya or the three great poets of Telugu for this mammoth effort. Other such translations like Marana's Markandeya Purāṇam, Ketana's Dasakumara Charita, Yerrapragada's Harivamsam followed.

Literary activities flourished, during the rule of Vijayanagara dynasty. Kṛṣṇadevaraya's time (16th century) is considered the golden age in the history of Telugu literature. The king, a poet himself, introduced the Prabandha (a kind of love poetry) in Telugu literature with his Amukta Malyada. His court had the Ashtadiggajas (literal: eight elephants) who were then known to be the greatest of poets of that time. Tyagaraja (1767-1847) of Thanjavur composed devotional songs in Telugu, which form a big part of the repertoire of Karnatak music. In Kannada, another South Indian language, the Virasaiva movement led to the composition of Vachakam containing the sayings of Basava.

In the north notable works in the vernacular languages included the Ramacharitmanas of Tulsidas and the Sursagar of Surdas, both in Hindi, Chatanyamrita of Sri Chaitanya and Mangal kavyas in Bengali, the devotional compositions of Namdev in Marathi, the poems of Mirabai in Gujarati, the Gitagovinda of Jaidev and so on. Both the epics, the Rāmāyaṇa and the Mahābhārata were translated into many local languages.

EPISTEMOLOGY

In this section we will focus on the theory of knowledge, not so much on the end goal of jivanmuktiviveka but on one of the paths to such a goal, namely the path of Jnana or Knowledge. What is knowledge? How do we acquire knowledge? And if and when acquired how do we know whether the knowledge so acquired is the right knowledge and whether it is relevant to the problems faced by the individual? Before we begin, we recollect why we invoke Shānti 3 times in order to grant us the wisdom and equanimity to overcome 3 categories of possible obstacles

- **Adhi Daivika represents cosmic phenomena such as Meteorites, Sun spots which cause a disruption in the planet over which we have absolutely no control.**
- **Adhi Bhautika encompass Terrestrial phenomena such as fire floods, landslides. No single individual can do anything to alter these events, but a society and a nation can do something about such phenomena.**
- **Adhyātmika, are purely subjective traits such as inertia, lack of faith, insincerity and such, arise from our own negativities and hence are entirely dependent on the choices one makes, every day of his or her life.**

We will briefly touch on the following topics Epistemology of the Dhārmik tradition (Epistemology is the study of the origin, nature and validity of knowledge).

TABLE 3 MEANS OF CREATING KNOWLEDGE (PRĀMANYA)
Darśana दर्शण vision, philosophical doctrine

Pramāṇa -प्रमाण Right Knowledge
There are several approaches to accumulating and fine tuning knowledge
Pratyakṣa, प्रत्यक्ष, direct perception, for example ocular proof.
Anumāna, अनुमान, inference.
Upamāna, उपमान Use of analogy, simile
Shabdabodha (शब्दबोध) Cognition caused by an utterance based on Authoritative or scriptural testimony e.g., The Bhagavad Gita. Who determines whether a particular scripture is authoritative? Ultimately it is the individual.
Arthāpatti अर्थापत्ति (Postulate, Arthāpatti —(Sanskrit: "the incidence of a case"), the knowledge gained by circumstantial implication, superimposing the known knowledge on an appearing knowledge that does not concur with the known knowledge,
Upapatti (उपपत्ति (Necessity of proof or demonstration)
Viparyāya, विपर्याय)Wrong knowledge or lack of discrimination)
Vikalpa विकल्प (Fancy or Verbal delusion)
Nidra (sleep) निद्र

Smriti स्म्रति

The Shad-Darśanas

THE Shad-Darśanas are six great works (Philosophical systems) that shed light on Indian Ethos, the way the Indic looks at the world, which many mistakenly consider to be based on blind belief. Explaining the *Vedas* explicitly, they share with the world the wisdom contained therein. The six texts are based on

(a) The *Veda*

(b) Non-belief and

(c) Inner Vision.

They explain incidents and events that pertain to all the three times of past, present, and future. They have taught man how to do away with suffering, restlessness etc., and lead a good life by removing the dirt in him. They explicitly state that the *Vedas, the Vedanta* and the knower *of Vedas* are all one and the same. They explain the nature of the mind which is responsible for all Intelligence, intellect, and discrimination. These six great *Darśanas* (texts) are:

(a) *Nyāya*

(b)Vaiseshika

(c) *Saṇkhya (सांख्य)*, IAST: Sāṇkhya - 'enumeration

(d) *Yoga*

***(e) Pūrva-Mīmāmsa* and**

(f) *Uttara Mīmāmsa.*

PRAMĀṆA– THEIR NUMBER

Different scholars have given different opinions about the number of the essential Pramāṇa. Charvakas, (the atheists) have declared that there is only one Pramāṇa and that is Pratyakṣa.

Buddhists and the scholars belonging to the Kanāda school of thought include Anumāna also and say that **Pramāṇa** are two in number. Anumāna is inference. It is not proper to think that everything in this world can be understood by Pratyakṣa (direct perception) alone. Inference done with due caution also worthy of believing. Therefore Anumāna is also a Pramāṇa – opine these scholars.

The proponents of Sāṇkhya school of thought say that along with Pratyakṣa and Anumāna, Shabda is also a Pramāṇa. Shabda means words of a learned and trustworthy person. It is not enough to limit ourselves to direct perception or inference. We should believe the words of men of wisdom – this is the idea of the Sāṅkhya. The Vedas are the most superior in this category. Therefore, the Vedas are referred to as Sāṃhita. They are also called as Agama.
The scholars belonging to Tārka (logic) school of thought say that along with Pratyakṣa, Anumāna and, even Upamāna (simile) should also be considered as a Pramāṇa. Upamāna is similarity. For example, we showed a flying creature to a person and told him that it was a crow. After sometime, a similar looking animal appeared and this person can easily say that it is also a crow. From where did he get this knowledge? He got this knowledge by comparing this object with the one he had seen earlier. Because Upamāna helps in knowing an object, it should also be considered as a Pramāṇa – is the opinion of the logicians.
The scholars of Mīmāmsa ṡāstra (particularly the Prābhākarā school) include Arthāpatti along with the above four. Arthāpatti is postulation. It is described as the necessary supposition of an unperceived fact that demands an explanation. For example, if a person is fasting during the day and yet is growing fat, we are forced to conclude that he is eating at night. Such postulation is Arthāpatti. In simple language, Arthāpatti means that which easily becomes evident.
This is not mere imagination. Here there is a clear understanding that in the absence of a particular act, what has become evident could not have happened at all. We see many such examples in life. Therefore Arthāpatti should also be considered as a Pramāṇa is the opinion of the Mīmāmsa scholars.
Another school pertaining to Mīmāmsa Ṡāstra, the **Kumārila Bhaṭṭa** (कुमारिल भट्ट), school opines that along with the above five

- **Pratyakṣa,**
- **Anumāna,**
- **Upamāna and**
- **Arthāpatti, another Pramāṇa, namely**
- **Anupalabdhi should also be included**.

The knowledge that a particular object is not present (here) is Anupalabdhi. If there is a tree before us, we will perceive it. For this, the eyes serve as Pramāṇa. If there is nothing before us, the eyes do not say 'there is no tree here', 'there is no jar here', 'there is no rock here' and so on. Therefore, there is a Pramāṇa that tells us about the non-existence of objects. It is called Anupalabdhi. When we do not perceive a pot on a table before us, we come to know that it does not exist. Thus, it is a negative means of knowledge.
The historians suggest that two more Pramāṇas, namely, Sambhava and Aitihya should also be considered along with the above six Pramāṇas.
Sambhava means educated guess. For example, when we take a vessel to an experienced cook, he can say with certainty that a particular amount of rice can be cooked in that vessel. That which brings about such knowledge is called **SAMBHAVA PRAMĀṆA.**

Aitihya means traditional instruction that has been handed down through generations. Some say that even this should be considered as a Pramāṇa. The Mīmāmsakaras have thoroughly examined all the above Pramāṇas and have declared that the primary Pramāṇas are six in number. According to Vedanta,

- **Pratyakṣa,**
- **Anumāna,**
- **Upamāna, Agama,**
- **Arthāpatti**
- **Upapatti and**
- **Anupalabdhi are the six accepted Pramāṇas.**
  Therefore Vedantists are also referred to as Shat-Pramāṇa-Vādins. (Shat=six, Pramāṇa=evidence, Vādi=proponent)

Nyāya Darśana* forms the framework for other *Darśanas
It is also called Gautama Ṣāstrā. This forms the framework for the remaining five *DarŚanas.* We have measures to judge the quantity and volume of material in the world. The following are the means by which we measure the efficacy or truth of the knowledge

- ***Pratyakṣa* (direct perception)**
- ***Anumāna* (inference)**
- ***Upamāna* (comparison)and**
- ***Shabdha* (sound).**

Pratyakṣa Pramāṇa: This may be rendered as direct proof, as it is perceived by the sense organs. These organs are merely sensory measuring instruments. The mind enters them and helps them to function. There are some limitations on the senses like disease and imperfection that make proof obtained by this method to be infirm. For example, a normal eye can see all colors; a jaundiced eye sees everything as yellow. It can be concluded, therefore, direct proof is not complete evidence for real justice.

Inference or Anumāna Pramāṇa: This is based on doubt and inference. One sees cranes in the distance, for example, and infers that water could be available there. Similarly, one infers about fire by seeing the smoke, from the *Svabhāva* (natural traits), one makes about the Svarūpa (the real form). Inference or **Anumāna** is defined as that cognition which presupposes some other cognition. It is knowledge which arises (anu) or is inferred from a basic hypothesis, axiom, or other knowledge. According to Nyāya, Anumāna (inference) is the efficient instrument (karana) of inferential knowledge (anumiti). Anumiti is knowledge that arises from parāmarsa. Parāmarsa is a complex cognition which arises from a combination of the knowledge of invariable concomitance (vyāptijnāna) and that of the presence of the linga in the Pakṣa -- technically known as Pakṣadharmatājnāna.

Analogy or Upamāna Pramāṇa*:* This kind of testimony is based on comparison. It enables us to understand many things that cannot be otherwise easily understood, by comparing them to some others that can be. By studying the *Prāthibhasika* (apparent reality) and the *Vyāvahārika* (empirical reality), one can infer about *the Pāramārthika* (transcendental). For example, by studying the foam (empirical reality) that originates from the waves (apparent reality), one can understand the reality of the Ocean (transcendental reality). This is possible because both the foam and the waves originate from the Ocean, and mirror its character in them. This is the example cited for all beings emanating from the Ocean of Divinity as waves.

Shabdha Pramāṇa: It is the proof garnered on the basis of sound. It is believed wrongly especially in the

west that It is the attempt by orthodoxy to avoid giving a rationale for a particular belief and is considered to be the ultimate proof. It is based on the testimony of the sound that the *Vedas,* Vedāngas*,* Upanishad**,** and the Bhagvad Gīta came into existence, but, to be able to perceive this testimony, one must be properly attuned and extremely careful. It needs one to travel beyond the mind and the senses. At this stage of *Samāna chittha* (mental equanimity), sound becomes the very form of God. The eight forms of God are *Shabdha Brahma mayee* (sound), *Charāchara mayee* (All pervasiveness), *Parāthpara mayee* (Transcendental nature), *Vāng mayee* (speech), *Nityānandha mayee* (blissful), *Jyothir mayee* (Effulgence), *Māya mayee* (illusion), and *Shreemayee* (prosperity).

THE DISTINCTION BETWEEN ŚRUTI AND SMRITI REVISITED

We have already referred to the distinction between Śruti and Smriti and the reasons why the ancients made such a distinction. These have to do with, among other factors, the status of an individual's knowledge and his stage in one's life. Suffice it to say that in an era where it appears to be politically correct to discard the presuppositions that are made by the Śruti , a more rational approach would be to realize that the axioms that one wishes to retain as a fundament (pramāṇa) are highly dependent on the stage of one's life . and that the 'one size fits all approach that the Occident, in general and the Abrahamic faiths in particular adopt is certainly inadequate for the challenges humanity will face in the coming decades and centuries. As an alternative one could do worse than follow the broad directions laid out in the Smriti. As one matures, one can begin to discard each presupposition that does not meet the requisite pramāṇa.

FIGURE 3 THE CHURNING OF THE OCEAN FRIEZE AT ANGKOR WAT CORRIDOR WALL



It has been asserted, quite wrongly in my view, that anybody can call himself a Hindu. This would be a grave mistake. Superficially it appears that the Sanatana Dharma asks nothing of you. After all there is no catechism. There is no injunction to pray a certain number of times a day facing prescribed direction, there is no requirement to go to a temple. In truth, there is no prophet to demand absolute allegiance on pain of excommunication. Finally there is no overwhelming urge to convert people to your faith. The lack of a titular head has been noted by the adversarial faiths, who have rushed into India in great numbers using financial incentives to convince unsuspecting folk to embrace the Valhalla where a Prophet from a bygone age and/or a distant land, presumes to instruct you on how you should lead your life.

I will not deflect any further into these theological arguments, but the reason I digressed was to show

that, never in the history of the dharma, has anybody been beheaded for holding a certain Weltanschauung, or to put it in pithy terms as a canonical example, for believing or not believing in the geocentric model of the solar system. This is the single major reason why the Indic Ancients were so successful in ferreting out the secrets of the universe. But the occident will not even accept that the Indics made significant advances much less admit to the freedom he had while discovering the secrets of the sky. To embrace the Dharma way, is essentially synonymous with the freedom to think and to be the best you can be. In those instances that the individual does not transgress the civil and criminal laws of the country but is in violation of the Dhaarmic way, he or she will reap the consequences of a suboptimal life.



FIGURE 4 THE CHURNING OF THE OCEAN SCULPTURE AT BANGKOK'S SUVARNABHŪMI INTERNATIONAL AIRPORT

THE INDIC TRADITIONS IN THE COMPUTATIONAL SCIENCES

While the ancient Indics may have produced a copious amount literature in the literary field, what is the relevance of this to Mathematics and Astronomy? The Indic was an eminently practical individual. Once he had decided to map the heavens he went about developing the tools to determine the nature of the heavenly motions. We have seen in chapter VI how he established the structure of calendrical astronomy, that survived over 5 millennia from the time of Dīrghatamas and continued on through the

millennia with names such as Yājnavalkya, Parasara, Bhishma, Garga, Lagadha, Āryabhaṭa, Varāhamihīra, Brahmagupta, the 2 Bhāskaras, and finally with the modern era the Daivajnās, the Suris of the Telugu land, the brilliant Kerala Astronomer Nīlakaṇṭa, the man who knew infinity Ramanujan, and the incomparable Chandrasekhar who was able to see the secrets of the cosmos even where light could not escape.

APPENDIX E
WHAT THE REST OF THE WORLD SAID ABOUT THE INDIC CONTRIBUTIONS

The contributions of the ancient Indics are usually overlooked and rarely given sufficient credit in Western Texts (see for instance FAQ on Indic mathematics) (www. Indicstudies.us/mathematics/faqmath.html) The Wikipedia section on Indian Mathematics says the following;

Unfortunately, Indian contributions have not been given due acknowledgement in modern history, with many discoveries/inventions by *Indian mathematicians* now attributed to their western counterparts, due to *Eurocentrism*.

The historian *Florian Cajori*, one of the most celebrated historians of mathematics in the early *20th century*, suggested that "*Diophantus*, the father of Greek *algebra*, obtained the first algebraic knowledge from India." This theory is supported by evidence of continuous contact between *India* and the *Hellenistic world* from the late *4th century BC*E, and earlier evidence that the eminent *Greek mathematician Pythagoras* visited India, which further 'throws open' the Eurocentric ideal.

More recently, evidence has been unearthed that reveals that the foundations of *calculus* were laid in India, at the *Kerala School*. Some allege that *calculus* and other mathematics of India were transmitted to *Europe* through the trade route from *Kerala* by traders and *Jesuit* missionaries. Kerala was in continuous contact with *China*, *Arabia*, and from around *1500*, Europe as well, thus transmission would have been more probable than possible.

However in recent years, there has been greater international recognition of the scope and breadth of the Ancient Indic contribution to the sum of human knowledge especially in some fields of science and technology such as Mathematics and Medicine. Typical of this new stance is the following excerpt by researchers at St. Andrews in Scotland titled '*An overview of Indian mathematics*'. *It is without doubt that mathematics today owes a huge debt to the outstanding contributions made by Indian mathematicians over many hundreds of years. What is quite surprising is that there has been a reluctance to recognize this and one has to conclude that many famous historians of mathematics found what they expected to find, or perhaps even what they hoped to find, rather than to realize what was so clear in front of them.*

We shall examine the contributions of Indian mathematics in this article, but before looking at this contribution in more detail we should say clearly that the "huge debt" is the beautiful number system invented by the Indians on which much of mathematical development has rested. ***Laplace*** put this with great clarity:

"The ingenious method of expressing every possible number using a set of ten symbols (each symbol having a place value and an absolute value) emerged in India. The idea seems so simple nowadays that its significance and profound importance is no longer appreciated. Its simplicity lies in the way it facilitated calculation and placed arithmetic foremost amongst useful inventions. The importance of this invention is more readily appreciated when one considers that it was beyond the two greatest men of Antiquity, *Archimedes,* and *Apollonius*. "'

We shall look briefly at the Indian development of the place-value decimal system of numbers later in this article and in somewhat more detail in the separate article Indian numerals. First, however, we go back to the first evidence of mathematics developing in India.

Histories of Indian mathematics used to begin by describing the geometry contained in the Sulva Sūtras but research into the history of Indian mathematics has shown that the essentials of this geometry were older being contained in the altar constructions described in the Vedic mythology text the *Śatapatha*

Brāhmaṇa and the *Taittiriyā Saṃhitā.* Also it has been shown that the study of mathematical astronomy in India goes back to at least the third millennium BC and mathematics and geometry must have existed to support this study in these ancient times. Equally exhaustive in its treatment is the Wiki encyclopedia, where in general the dates are still suspect. See for instance the Wikipedia on evidence from Europe that India is the true birthplace of our numerals.

EVIDENCE FROM EUROPE THAT INDIA IS THE TRUE BIRTHPLACE OF OUR NUMERALS

The views of savants and learned scholars from a non-Indian tradition about Indian mathematics are presented here. Note that most of these are dated prior to the1800's, when India was still untainted with the prefix of being a colonized country. Severus Sebokht of Syria in 662 CE: (the following statement must be understood in the context of the alleged Greek claim that all mathematical knowledge emanated from them);
"I shall not speak here of the science of the Hindus, who are not even Syrians, and not of their subtle discoveries in astronomy that are more inventive than those of the Greeks and of the Babylonians; not of their eloquent ways of counting nor of their art of calculation, which cannot be described in words - I only want to mention those calculations that are done with nine numerals. If those who believe, because they speak Greek, that they have arrived at the limits of science, would read the Indian texts, they would be convinced, even if a little late in the day, that there are others who know something of value".
SAID AL-ANDALUSI'S remarks on India have been mentioned in the Prologue[305]. The respect that the Indic commanded, was not at the business end of a piece of weaponry but was because of his reputation for learning and the integrity with which he dealt with others, qualities that the Occidental did not put a high value on, when he first broke into India.

1.ALBERT EINSTEIN in the 20th century also comments on the importance of Indian arithmetic: "*We owe a lot to the Indians, who taught us how to count, without which no worthwhile scientific discovery could have been made.*"

2.QUOTES FROM *LIBERABACI* (BOOK **OF THE ABACUS) BY LEONARDO OF PISA**, aka Fibonacci (1170-1250): The nine Indian numerals are 1,2,...9; with these nine and with the sign 0 which in Arabic is *sifr,* any desired number can be written. (Fibonacci learnt about Indian numerals from his Arab teachers in North Africa) .Fibonacci introduced Indian numerals into Europe in 1202CE. Note that just because Fibonacci was convinced that the Indian number system was the greatest thing since sliced bread, it does not mean that they achieved ready acceptance in Europe. It was not until the advent of Simon Stevin (and the challenge problems posed by Pierre Fermat) that Europe realized how far behind they were.

3. G HALSTEAD...The importance of the creation of the zero mark can never be exaggerated. This giving to airy nothing, not merely a local habituation and a name, a picture, a symbol but helpful power, is the characteristic of the Hindu race from whence it sprang. No single mathematical creation has been more potent for the general on go of intelligence and power. [CS, P 5]

Most of the following quotes are from George Ifrah's book Universal History of Numbers;

The real inventors of this fundamental discovery, which is no less important than such feats as the mastery of fire, the development of agriculture, or the invention of the wheel, writing or the steam

[305] *see page endnote 4 on page 4*

engine, were the mathematicians and astronomers of the ancient Indian civilization: scholars who, unlike the Greeks, were concerned with practical applications and who were motivated by a kind of passion for both numbers and numerical calculations. There is a great deal of evidence to support this fact, and even the Arab Muslim scholars themselves have often voiced their agreement. The following is a succession of historical accounts in favor of this theory, given in chronological order, beginning with the most recent;

4. **HERMAN HANKEL** (**FEBRUARY 14, 1839 - AUGUST 29, 1873**) it (Bhāskara's Chakravala methods) is beyond all praise. It is certainly the finest thing achieved in the theory of numbers before Lagrange.

5. P. S. LAPLACE (1814 CE): "The ingenious method of expressing every possible number using a set of ten symbols (each symbol having a place value and an absolute value) emerged in India. The idea seems so simple nowadays that its significance and profound importance is no longer appreciated. Its simplicity lies in the way it facilitated calculation and placed arithmetic foremost amongst useful inventions. The importance of this invention is more readily appreciated when one considers that it was beyond the two greatest men of Antiquity, Archimedes, and Apollonius." [Dantzig. p. 26]

6. **J. F. MONTUCLA (1798 CE):** "The ingenious number-system, which serves as the basis for modern arithmetic, was used by the Arabs long before it reached Europe. It would be a mistake, however, to believe that this invention is Arabic. There is a great deal of evidence, much of it provided by the Arabs themselves that this arithmetic originated in India." [Montucla, I, p. 375J

7. JOHN WALLIS (1616-1703 CE) referred to the nine numerals as *Indian figures* [Wallis (1695), p. 10]

8. **CATANEO (1546 CE)** *le noue figure de gli Indi,* "the nine figures from India". [Smith and Karpinski (1911), p.3

9. **WILLICHIUS (1540 CE)** talks of *Zyphrae! Nice,* "Indian figures". [Smith and Karpinski (1911) p. 3]

10. **THE CRAFTE OF NOMBRYNGE (c. 1350 CE),** the oldest known English arithmetical tract: II fforthermore ye most vndirstonde that in this craft ben vsed teen figurys, as here bene writen for esampul 098 ^ 654321... In the quych we vse teen figwys of Inde. Questio II why Zen figurys of Inde? Soiucio. For as I have sayd afore thei werefondefrrst in Inde. [D. E. Smith (1909)

11. **PETRUS OF DADA (1291 CE)** wrote a commentary on a work entitled *Algorismus* by Sacrobosco (John of Halifax, c. 1240), in which he says the following (which contains a mathematical error): *Non enim* omnis *numerus per quascumquefiguras Indorum repraesentatur* "Not every number can be represented in Indian figures". [Curtze (1.897), p. 25

12. Around the year 1252 CE, Byzantine monk **MAXIMUS PLANUDES (1260—1310**) composed a work entitled *Logistike Indike* ("Indian Arithmetic") in Greek, or even *Psephophoria kata Indos* ("The Indian way of counting"), where he explains the following: "There are only nine figures. These are: 123456789 [figures given in their Eastern Arabic form]

13. A sign known as *tziphra* can be added to these, which, according to the Indians, means 'nothing'. The nine figures themselves are Indian, and *tziphra* is written thus: 0". [B. N., Pans. *Ancien Fonds grec,* Ms 2428, f" 186 r"]

14. Around 1240, **ALEXANDRE DE VILLE-DIEU** composed a manual in verse on written calculation (algorism). Its title was *Carmen de Algorismo,* and it began with the following two lines: *Haec algorismus ars praesens dicitur, in qua Talibus Indorumfruimur bi's quinquefiguris*
"Algorism is the art by which at present we use those Indian figures, which number two times five". [Smith and Karpinski (1911), p. 11]

15. In 1202 CE, **LEONARDO OF PISA (KNOWN AS FIBONACCI, SHORT FOR FiILIOUS BoONACCI OR SON OF BONACCIO),** after voyages that took him to the Near East and Northern Africa, and in particular to Bejaia (now in Algeria), where he was educated, wrote a tract on arithmetic entitled *Liber Abaci* ("a tract about the abacus" and sometimes translated as a book of Calculation), in which he explains the following: "My father was a public scribe of Bejaia, where he worked for his country in Customs, defending the interests of Pisan merchants who made their fortune there. He made me learn how to use the abacus when I was still a child because he saw how I would benefit from this in later life. In this way I learned the art of counting using the nine Indian figures... The nine Indian figures are as follows: 987654321 [figures given in contemporary European cursive form]. "That is why, with these nine numerals, and with this sign 0, called zephirum in Arab, one writes all the numbers one wishes."[Boncompagni (1857), vol.1]. Clearly Fibonacci regarded the achievement of the number system was a significant one. Fibbonacci was by all accounts a gifted mathematician for his time in Europe and the Fibonacci Sequence is named after him.

16. RABBI ABRAHAM BEN MEIR BEN EZRA (1092—1167 CE), after a long voyage to the East and a period spent in Italy, wrote a work in Hebrew entitled: *Sefer ha mispar* ("Number Book"), where he explains the basic rules of written calculation.

He uses the first nine letters of the Hebrew alphabet to represent the nine units. He represents zero by a little circle and gives it the Hebrew name of *galgal* ("wheel"), or, more frequently, *sfra* ("void") from the corresponding Arabic word.

However, all he did was adapt the Indian system to the first nine Hebrew letters (which he naturally had used since his childhood). In the introduction, he provides some graphic variations of the figures, making it clear that they are of Indian origin, after having explained the place-value system: "That is how the learned men of India were able to represent any number using nine shapes which they fashioned themselves specifically to symbolize the nine units." (Silberberg (1895), p.2: Smith and Ginsburg (1918): Steinschneider (1893)1

17. Around the same time, **JOHN OF SEVILLE** began his Liber algorismi de practica arismetrice ("Book of Algorismi on practical arithmetic") with the following: "A number is a collection of units, and because the collection is infinite (for multiplication can continue indefinitely), the Indians ingeniously enclosed this infinite multiplicity within certain rules and limits so that infinity could be scientifically defined: these strict rules enabled them to pin down this subtle concept. [B. N., Paris, Ms. lat. 16 202, p 51: Boncompagni (1857), vol. I, p. 261]

18. **ROBERT OF CHESTER, CA. 1143 CE**, wrote a work entitled: *Algoritmi de numero Indorum* ("Algoritmi: Indian figures"), which is simply a translation of an Arabic work about Indian arithmetic. [Karpinski (1915); Wallis (1685). p. 121

19. **BISHOP RAYMOND OF TOLEDO , CA. 1140 CE** gave his patronage to a work written by the converted Jew Juan de Luna and archdeacon Domingo Gondisalvo: the *Liber Algorismi de numero Indorum* ("Book

of Algorismi of Indian figures) which is simply a translation into Spanish and Latin version of an Arabic tract on Indian arithmetic. [Boncompagni (1857), vol. 11

20. **ADELARD OF BATH, CA. 1130 CE**, wrote a work entitled: *Algoritmi de numero Indorum* ("Algoritmi: of Indian figures"), which is simply a translation of an Arabic tract about Indian calculation. [Boncompagni (1857), vol. Ii

21. **WILLIAM OF MALMESBURY,** CA**. 1125 CE,** The Benedictine chronicler wrote *De gestis regum Anglorum,* in which he related that the Arabs adopted the Indian figures and transported them to the countries they conquered, particularly Spain. He goes on to explain that the monk Gerbert of Aurillac, who was to become Pope Sylvester II (who died in 1003) and who was immortalized for restoring sciences in Europe, studied in either Seville or Cordoba, where he learned about Indian figures and their uses and later contributed to their circulation in the Christian countries of the West. L Malmesbury (1596), f" 36 r'; Woepcke (1857), p. 35J

22. **WRITTEN IN 976 CE IN THE CONVENT OF ALBELDA** (near the town of Logroño, in the north of Spain) by a monk named **Vigila, the *Coda Vigilanus***[306] contains the nine numerals in question, but not zero. The scribe clearly indicates in the text that the figures are of Indian origin:

"The same applies to arithmetical figures. It should be noted that the Indians have an extremely subtle intelligence, and when it comes to arithmetic, geometry and other such advanced disciplines, other ideas must make way for theirs. The best proof of this is the nine figures with which they represent each number no matter how high. This is how the figures look:

9 8 7 6 5 4 3 2 1

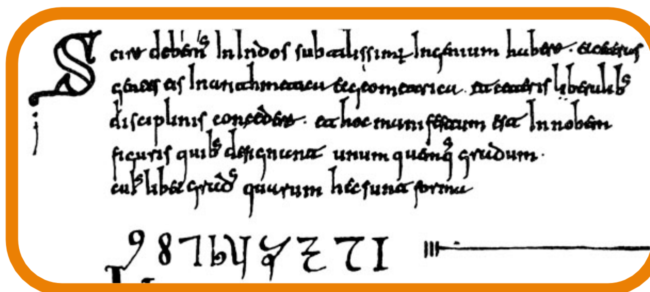


FIGURE 1
CODEX VIGILANUS MENTIONS INDIAN NUMBER SYSTEM EXPLICITLY IN 976 CE

23. AL-KHWARISMI (783-850 CE) Popularized Indian numerals, mathematics including Algebra in the Islamic world and the Christian West .Algebra was named after his treatise 'Al jabr wa'l Muqabalah'' which when translated from Arabic means 'Transposition and Reduction'. Little is known about his life except that he lived at the court of the Abbasid Caliph al Ma'amun, in Baghdad shortly after Charlemagne was made emperor of the west. And that he was one of the most important Wisdom (Bayt al Hikma)

Portrait on wood made in 1983 from a Persian illuminated manuscript for the l200th anniversary of his birth. Museum of the Ulugh Beg Observatory. Urgentsch (Kharezm). Uzbekistan (ex USSR). By calling one of its fundamental practices and theoretical activities the algorithm computer science commemorates this great Muslim scholar.

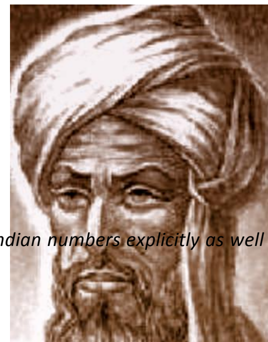


FIGURE 2 MUHAMMAD BEN MUSA AL-KHWARIZMI (circa 783—850.).

[306] *This is probably the first text in Mathematics in the west that mentions the Indian numbers explicitly as well as state categorically the superiority of the ancient Indic geometry*

INDIAN MATHEMATICS

"The first mathematics which we shall describe in this article developed in the Indus valley. The earliest known urban Indian culture was first identified in 1921 at Harappa in the Punjab and then, one year later, at Mohenjo-Daro, near the Indus River in the Sindh. Both these sites are now in Pakistan but this is still covered by our term "Indian mathematics" which, in this article, refers to mathematics developed in the Indian subcontinent. The Indus civilization (or Harappan civilization as it is sometimes known) was based in these two cities and also in over a hundred small towns and villages. It was a civilization which began around 2500 BC and survived until 1700 BC or later. The people were literate and used a written script containing around 500 characters which some have claimed to have deciphered but, being far from clear that this is the case, much research remains to be done before a full appreciation of the mathematical achievements of this ancient civilization can be fully assessed. "

The above statement must be revised based on new archaeological discoveries. More than 400 sites have been found along the banks of the dried up river bed of the ancient river Sarasvati. These sites include the submerged city of Bet Dwaraka, the city ruled by Sri Kṛṣṇa during the episodes of the Mahābhārata and the great Bharata war that is described in detail in that epic. The important point to note is that a prerequisite to do numerical work is a script. So, there must have been a script by the time the Sarasvati Sindhu civilization was flourishing not just centered in the two cities of Mohenjo Daro and Harappa but along dozens of urban towns and cities like Dholavira, Lothal, Dwaraka and others. European historians often wonder what happened to the denizens of the Indus Valley civilization. Ockham's razor suggests the right answer. Nothing catastrophic happened to these people and we the modern Indics are the descendants of this civilization which was spread over a huge area stretching from Haryana in the north to the present day province of Mahārashtra to places like Prathishtan (later Pathan) which eventually became the capital of the Sātavāhana Empire and in fact was a successor to the Urban civilizations that existed prior to them. This makes eminent sense because the word Brahmi signifies the goddess Sarasvati (consort of Brahma) and is therefore also considered to be the Guardian deity of Knowledge and the one who is credited with blessing us with the gift of a script. There are a group of Brāhmaṇas in the Konkan area of present day state of Karnataka who call themselves Sarasvath Brāhmaṇas and legend has it that they migrated from the banks of the Sarasvati river when it eventually dried out. In fact the Gowda Sarasvat Brāhmaṇas have done extremely well over the succeeding centuries and have prospered far in excess of their proportion in the population. In fact our family records show that about 15 generations ago my ancestor by the name of **Hanuman Bhat** migrated to the Andhra country, to escape the turmoil caused by the interminable wars and the tyranny of Aurangzeb, from the area which is considered present day Konkan.

We often think of Egyptians and Babylonians as being the canonical examples of the origin of mathematical skills around the period of the Indus civilization, yet V G Childe in *New Light on the Most Ancient East* (1952) wrote:-

India confronts Egypt and Babylonia by the 3rd millennium with a thoroughly individual and independent civilization of her own, technically the peer of the rest. And plainly it is deeply rooted in Indian soil. The Indus civilization represents a very perfect adjustment of human life to a specific environment. And it has endured; it is already specifically Indian and forms the basis of modern Indian culture.

That the contributions of the Indics were considerable was therefore in little doubt among the Europeans in the middle ages. It is only when we come to the colonial era that the British had a reluctance to admit this glaring fact. Even after India became a republic the practice of naming of new developments after a European or a White Caucasian, regardless of whether there have been names of contributors that are not of Occidental descent continues on till this day. We will describe one such

instance in the area of statistical estimation in the endnotes[307]. While the incident itself is laced with humor and sarcasm, it is interesting that one of the interlocutors (DV Lindley) who did not mention Rao's name when referring to the result, began defending his lack of due diligence by complaining that the result ought to have been stated in the introduction, and he sought to divert attention from his own excess of intellectual inertia to the accusation that Rao did not realize the value of his own work by not drawing attention to his result by highlighting it in the introduction. In choosing the same excuse that Morris Kline gave a half a century before him that the ancient Indics did not realize the value of their work, as an excuse to avoid giving them credit, he exhibits the mendacity of many in the occident who think they can get away with it as long as the work is not done in the occident. The least that we expect from the occidental is that he exhibits a degree of originality while trotting out his excuses. Even a child knows that he or she cannot use the excuse that the dog ate my homework more than a couple of times.

[307] RAO-BLACKWELL THEOREM and RAO-BLACKWELLIZATION in the theory of statistical estimation. The "Rao-Blackwell theorem" recognizes independent work by C. R. Rao (1945 Bull. Calcutta Math. Soc. 37, 81-91) and David Blackwell (1947 Ann. Math. Stat., 18, 105-110). The name dates from the 1960s for previously the theorem had been referred to as "Blackwell's theorem" or the "Blackwell-Rao theorem." The term "Rao-Blackwellization" appears in Berkson (J. Amer. Stat Assoc. 1955) ((From David (1995).)

In an Interview (p. 346) Rao shares some reminiscences about getting his name attached to the result, which may reflect more generally on the practice of EPONYMY. When Rao objected to Berkson's use of Blackwellization Berkson replied that Raoization by itself "does not sound nice." The other memory was of an exchange with D. V. Lindley who had attributed the result to Blackwell. When Rao wrote to Lindley pointing out his priority, Lindley replied, "Yes, I read your paper. Although the result was in your paper, you did not realize its importance because you did not mention it in the introduction to your paper." Rao replied, saying that it was his first full-length paper and that he did not know that the introduction is written for the benefit of those who read only the introduction and do not go through the paper!

In Russia the name Rao-Blackwell-Kolmogorov theorem is used in deference to a 1950 article by Kolmogorov.

APPENDIX F
ABBREVIATIONS OF RESOURCE MATERIALS

COMPILED BY KOSLA VEPA, YUGABDA 5111, DWITIYAH PARĀRTHE, SVETAH VARĀHA KALPE, VAIVASVAT MANVANTRE, VAIŚĀKHĀ PRATIPADA

TABLE 1 ABBREVIATIONS

ABBREVIATIONS OF RESOURCE MATERIALS	
ASWI	Archaeological Survey of Western India ; particularly, vol. IV (1876-9) where the caves used in the present work are described, though not too well, even with the supplementary aid of Burgess's Buddhist Cave Temples.
ABY	*Āryabhaţīya* of Āryabhaţa 1b
AA	Aitreya Āranyaka
AitBr	Aitareya Brāhmaṇa; translation by A. B. Keith, in HOS 25.
AIAM	Ancient Indian Astronomy and Mathematics
ASIA	Annual Bibliography of Indian Archaeology (Leiden).
AE	Ancient Egypt
ABORI .	Annals of the Bhandarkar Oriental Research Institute (Poona)
AB	Āryabhaţa I
AS	Arka Somayājī
ADE	Astronomical Dating of Events and Select Vignettes from Indian History, Proceedings of Seminar on Distorted History at HEC 2007, www.lulu.com, ed. by Kosla Vepa
AGP	Agni Purāṇa
AI	Ancient India (Archaeological Dept. Publication, nos. 1-11).
AIHT	Ancient Indian Historical tradition FE Pargiter
AK	The Arthaśāstra of Kautilya (otherwise known as Chanakya, Vishnugupta, and Kautilya). Ed. T.
ALB	Al Biruni's India trans. Ed. Sachau, 2 vol. London 1910; 2 vol. in one. London 1914. Al Biruni was a Khwarizmian (A. D. 9731048); this work was written about A. D. 1030.
AM	Amarakosha
ARĀSI	Annual Report of the Archaeological Survey of India
ANT	Antiquity, a Quarterly Review or Archaeology, founded by the late O. G. S. Crawford
AHES	Archive for the History of the Exact Sciences
ABA	Artibus Asiae
ASA	Āryabhaţa Siddhānta of Āryabhaţa Ia
AP	The *Ashtādhyāyi* of Pāṇini by Srisa Chandra Vasu
ASB	Library of the Asiatic Society of Bengal, Kolkatta
AV	The Atharva-veda, mostly from W. D. Whitney's translation, HOS. 7-8; also the selections translated by M. Bloom field, SBE 42.
BD	Baudhāyana DharmaSūtra
BSS	Baudhāyana Sulva Sūtra

BG	Bhagavad Gita
BHP	Bhāgavata Purāṇa
BHAVP	Bhavishya Purāṇa
BC	Buhar collection of the National Library, Kolkatta
BSOAS	Bulletin of the School of Oriental and African Studies (of the University of London). ABBREVIATIONS AND BIBLIOGRAPHY
BRU	Brihat Āranyaka Upanishad
BHP	Brihat Parasara Horasastra
BRSAM	Brihat Saṃhitā
BRP	Brahma Purāṇa
BRSPS	Brahmasphuta Siddhānta
BRVP	Brahma Vaivarta Purāṇa
BEFEO	Bulletin de l'Ecole Francaise de L'extreme Orient
BRP	Brahmānda Purāṇa
BS	Brahmasputa Siddhānta by Brahmagupta
BRD	Brihat Devata
BASOR	Bulletin of the American Schools of Oriental Research.
CESS	Census of the Exact Sciences in Sanskrit, by David Pingree, in 5 volumes, series A
CHI	The Cambridge History of India, vol. I, "Ancient India E. J. Rapson, Cambridge 1922, 1935.
CII	Corpus Inscriptorum Indicum
CHUP	Chandogya Upanishad
CHAP	Chandra prajnāpati
CP	City Palace Museum Library, Jaipur
CSIR	Council of Scientific and Industrial Research
CFM	Cultural Foundations of Mathematics By CK Raju
DKA	F. E. Pargiter : " The Purāṇa text of the Dynasties of the Kali Age" (Oxford 1913); synoptic text and translation of the historical portion of the Purāṇas, still standard. For a general critical analysis of the Purāṇas, see R. C. Hazra: "Studies in the Purāṇic records on Hindu rites and customs ", Dacca, 1940.
DHI	Louis de la Vallee Poussin : " Dynasties et histoire de L'Inde depuis Kanaka jusqu'aux invasions musulmanes " (Paris 1935).
DN	Digha-Nikaya (Pali Text Society's edition).
DP	Dictionary of Pānini , SM Katre
ED	H. M. Elliot (ed. J. Dowson): "The history of India by its own historians; the Muhammadan period" (8 vol. London 1867 +).
EI	Epigraphica Indica
EC	Epigraphica Carnatika
FLEET	J. F. Fleet: "Inscriptions of the early Gupta kings and their successors" (Corpus Inscriptionum Indicarum III, Calcutta 1888). A revision has been announced, but not yet published, nor the supplementary volume of Sātavāhana and other epigraphs.
GOLA D	Gola Dipika
GP	Garuda Purāṇa

GLA	Graha Laghava
HV	Harivamsa, considered a Purāṇa, is part of the appendix to the Mahābhārata
IA	Indian Antiquary
IJHS	IJHS
IS	Indische Studien
ICHR	Indian Council of Historical Research
INDIA	Annual published since 1953 by the Publications Division of the Ministry of Information & Broadcasting, New Delhi; compiled by its Research and Reference section. This gives the statistics and general information of interest for the whole country.
IHQ	Indian Historical Quarterly
IMD	Indian Meteorological Department
INSA	Indian National Science Academy
IO	India Office Library, London (now part of British Library)
ITM	L. de la Vallee Poussin : "L'Inde aux temps des Mauryas et des barbares, Grecs, Scythes, Parthes et Yue-Tchi" (Paris 1930).
ITSING	Trans. J. Takakusu (Oxford, 1896) of I-Tsing's Record of the Buddhist Religion as practised by India and the Malay Archi pelago. I-Tsing spent 16 years in India, mainly to study monastic life and administration; of these, ten years circa 675-685 CE at Nalanda.
JA	Journal Asiatique
JAOS	Journal of the American Oriental Society
JRAS	Journal of the Royal Asiatic Society
JASB	Journal of the Asiatic Society of Bengal Three series, the society having once been changed into the 'Royal Asiatic Society', and afterwards merely the 'Asiatic Society*). The numismatic supplements to the middle series are paged separately.
JHA	Journal of the History of Astronomy
JBBRAS	Journal of the Bombay branch of the Royal Asiatic Society
JBORS	Journal of the Bihar and Orissa Research
JESHO	Journal of the Social and Economic History of the Orient; published at Leiden under the editorship of an international board
JOR	Journal of Oriental Research, Madras (from the Kuppuswami Sastri Research Institute, Mylapore, Madras).
JRAS	Journal of the Royal Asiatic Society of London
LB1	Laghu Bhaskariya of Bhāskara I
LB2	Lilāvati of Bhāskara II
K KAUM	Karana kaumudi
K Pad	Karana Paddhati
K PRAK	Karana Prakasa
K RATNA	Karana Ratna
KU	Katha upanishad
KBU	Kausitaki Brāhmaṇa Upanishad
KeU	Kena Upanishad
KHAND	Khandakhādyaka
KhB	Khuda Baksh Oriental Library (Bankpur), Bihar

KSS	Kripa Shankar Śukla
KP	Kurma Purāṇa
KVS	K V Sarma
LB	Laghu Bhāskariya
LM	Laghu Mānasa
LETTERS	Letters idifiantes et curiuses des missions etrangeres
LIC	L'Inde Classique by Louis Renou and Jean Filliozat
LP	Linga Purāṇa
MAL	Maulana Azad Library, Aligarh Muslim University
MAN	A journal for the study of anthropology.
MBH	Mahabharata, The great War of the Bharatas
MB1	Mahābhāskaryam of Bhāskara I
MSI	Mahā Siddhānta
MARP	Mārkandeya Purāṇa
MATP	Matsya Purāṇa
MEG	J. W. McCrindle: "Ancient India as described by Megasthenes and Arrian "(Calcutta 1926, badly reprinted from IA 1876-77). The text was published as selections of the quotations or reports of Megasthenes which survive in Strabo, Diodorus Siculus, and others by E. A. Schwanbeck, Bonn 1846.
MEST	McGraw Hill Encyclopedia of Science and Technology
NS	Naradiya siksha
NL	Nasariya Library
NMP	National Museum of Pakistan
ON	Otto Neugebauer
OUL	Osmania Universty Library
ONHAMA	Otto Neugebauer, A History of Ancient Mathematical Astronomy, SpringerVerlag,1975
PP	Padma Purāṇa
PSS	Panchasiddhāntika
PARAM	Parameṣvara
PHSPC	Project of History of Science, Philoosphy, and Culture in Indian Civilizations
PMS	Paitamaha Siddhānta
PS	Paulisa Siddhānta
QJRAS	Quarterly Journal of the Royal Aeronautical Society
RAVAM	Raghu Vamsa
RAMA	Rāmāyaṇa
RCRC	Report of the Calendar Reform Committee
RAS	Royal Astronomical Society
RGO	Royal Greenwich Observatory
RRSL	Records of the Royal Society of London
RB	Rajamriganka by Bhoja
RV	RV Saṃhitā
RV VJ	RV Vedāṅga Jyotiṣa
RS	Romaka Siddhānta
RSI	Royal Society of India
SK	Sankhya Karika

SEDA	Sanskrit English History, Vaman Shivram Apte
SB	Śatapatha Brāhmaṇa (contains Brihat – Aranyaka Upanishad)
SBE	Sacred Books of the East by Max Müller
SD	Siddhānta-darpanam of Nīlakaṇṭa Somayãji
SDCS	Siddhānta Darpana by Chandraśekhara Sāmanta BY Arun Kumar Upadhyay
SDS	S D Sarma
SDV	Sisya di Vridhida Tantra
SENSHUK	A history of Astronomy
SISE	Siddhānta Śekhara
SDS	Siddhānta Shiromani
SRS	S R Sarma
STV	Siddhānta tatva Viveka
SP	Siva Purāṇa
SAF	The South Asia File by Kosla Vepa
SS	Sulva Sūtras
SUP	Sūryaprajnāpati
SUSI	Sūrya Siddhānta
SUSIV	Sūrya Siddhānta Varāha Mihīra Redaction
TAITU	Taittiriyā Upanishad
TAITS	Taittiriyā Saṃhitā
TS	Tantrasamgraha of Nīlakaṇṭa Somayãji
TOAII	The Tradition of Astronomy in India, BV Subbarayappa
TS K	TS Kuppanna Sastry
UHN	Georges Ifrah The Universal History of Numbers
UP	Upanishad
V	*Varāhamihīra*
VS	Vaiseshika Sūtra
VAK	Vakyakarana
VAMP	Vāmana Purāṇa
VARP	Varāha Purāṇa
VG	Vatesvara's Gola
VSI	Vatesvara's Siddhānta
VAYP	Vāyu Purāṇa
VEDD	Vedartha dīpika
VP	VIshnu Purāṇa
VDP	Vishnudharmottara Purāṇa (contains Paitamaha Siddhānta)
VRNP	Vrhannaradhiya Purāṇa
VRVS	Vriddha Vaśiṣṭa Saṃhitā
VVBI	*VVB Institute* of Sanskrit and *Indological Studies*, Panjab University, Hoshiarpur
WIM	Richard Courant What is Mathematics
YB	Yuktibhāṣā
YV	Yajur Veda
YVVS	Yajur Veda Vājanaseyī
YJ	Yajur Veda Vedāṅga Jyotiṣa (Yājuṣa Jyotiṣa)
ZIM	Zij I Mohammad Shahi

APPENDIX G
PRIMARY AND OTHER SOURCES IN THE INDIC SCIENCES

TABLE 1 PRIMARY SOURCES

Aitreya Brāhmaṇa Aitreya Āranyaka Keith, Barriedale, Master Publishers, Delhi
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Āpastamba Sulva Sūtra, with commentaries of Kapardisvamin, Karavinda, Sundararaja, ed. by Sri Srinivasachar and S Narasimhachar, University of Mysore Oriental Publications, Sanskrit series, No.73, 1931
Artha Śāstra by Kautilya (ASK) by R Shamasastry, Chowkamba Sanskrit Pratishtan, Delhi, 2005, ISBN 61-7084-292-6, 81-7084-293-4
The Kautilıya Arthaśāstra, Kangle R P, Motilal Banarsidass, IN 3 VOLUMES, 1986, ISBN 81-208-0042-7
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Āryabhaţīyam with Vyakhya of Parameṣvara, Leyden, 1885, Kern, B. (ed.),
Āryabhaţīya – vyakhya by Sūryadeva Yajwan
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Āryabhaţa , Āryabhaţīya, ed. [with the commentary (bhāṣya) of Bhāskara I and Someshvara] K. S.Śukla, New Delhi: Indian National Science Academy, 1976.
(2) Āryabhaţīyabhāsya, 1977 (Available in Library of Congress)
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(2) Hindi Translation by L.C. Jain, Sholapur, 1963.
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KOSLA VEPA 5/23/2014 2:02 PM
Comment [6]:

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Bhatadipika - Commentary on Āryabhaţīya of Āryabhaţa I
Karmadipika - Commentary on Mahābhāskariya of Bhāskara I
Paramesvari - Commentary on Laghubhāskariya of Bhāskara I
Siddhāntadīpika - Commentary on Mahābhāskariyabhaṡya of Govindasvami

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DrgGaṇita - Description of the Drk system (composed in 1431 CE)
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APPENDIX H
SELECT BIBLIOGRAPHY

Very few of these books embrace the chronology that we espouse and the inferences that we make regarding the AIT, especially after the discovery of the desiccation of the Sarasvati River and the assumptions that we make regarding the Monarch who ruled Magadha during the time that Megasthenes was ambassador.

GENERAL INTEREST BOOKS ON INDIA AND HISTORY OF INDIA
THE GOOD, THE BAD AND THE UGLY

Abul Fazl, Akbarnama Jehangir Itikhab I Jahangiri
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APPENDIX I
RESOURCES FOR SANSKRIT MANUSCRIPTS IN INDIA

TABLE 1 RESOURCES FOR SANSKRIT MANUSCRIPTS IN INDIA	
Tamilnadu	
Chennai	Govt. Oriental Mss. Library
Chennai	Dr. U.V.S.I. Library
Chennai	RamaKṛṣṇa Mission
Thanjavur	TMSSM Library
Chennai	Kingdom of Trivandrum
Kanchipuram	Kingdom of Trivandrum
Kanchipuram	Sri Kanchi Sankar Math
Madurai	Saurashtra Sabha
Chennai	Kupuswami Sastri Res. Institute
Chennai	Adyar Library and Research Centre
Annamalai Nagar	Annamalai University Library
Thanjavur	Tamil University (Dept. of epigraphy)
Thanjavur	Tamil University (Dept. of His. & rare paper Mss.)
Thanjavur	Tamil University (Dept. of Palm leaf Mss.)
Madurai	Govt. Museum
Chennai	Institute of Asian Studies
Kanchipuram	Madurai Province Jesuit Archives
Shrothium	Nyāya Mīmāmsa Anusandhan Kendra
Madurai	Madurai Kamraj University
Shrotium Navalpakkam	Sri Hayagriva Mahāla Library
Thanjavur	Karandai Tamil Samgam
Mayauram Madurantakam	Vasudeva Brahmendra Sarasvati Library
	Ahobila Mutt Sanskrit College
Madurai	The Rameswaram Devasthanam Pātashāla
Kanchi Conjivaram Sriperambudur	The Upanishad Brahma Mutt
	The Ubhayavedanta Sanskrit College
Srirangam	The Srirangam Devasthanam Library
Chennai	Fort St. George Museum
Chennai	International Institute of Tamil Studies
Madurai	School Historical Studies, Madurai Kamaraj University
Mahārashtra	
Nagpur	Nagpur University Library
Pune	Bharata Itihasa Samsodhaka Mandala
Pune	Anandashram Sanstha
Pune	Bhandarkar Ori. Res. Institute
Pune	Vaidika Samsodhan Mandala

Mumbai	Jama Masjid Trust Library
Mumbai	Asiatic Society
Mumbai	Bombay University
Mumbai	Mahārashtra State Archives
Kolhapur	Shivaji University (BARR) Balasaheb Khandekar Library
Poona	Poona University, Laykar Library
Mumbai	Smt. Nathi Bai Damodar Thakarsey women's University Library
Nagpur	Anthropological Survey of India Library (Central)
Pune	The Mandalik Library, Fergusson College
Nasik	The Hamsaraj Pragji Thakersey College
Raipur	Raipur Sanskrit Pathsala
Nagpur	Jamia Arabia Islamia
Mumbai	Bombay University
Mumbai	Mahārashtra State Archives
Kolhapur	Shivaji University (BARR) Balasaheb Khandekar Library
Poona	Poona University, Laykar Library
Mumbai	Smt. Nathi Bai Damodar Thakarsey women's University Library
Nagpur	Anthropological Survey of India LIbrary (Central)
Pune	The Mandalik Library, Fergusson College
Nasik	The Hamsaraj Pragji Thakersey College
Raipur	Rajpur Sanskrit Pathsala
Nagpur	Jamia Arabia Islamia
Bombay (Colaba)	Anantacharya Indolofical Research Institute
Bombay	Bhartiya Vidya Bhawan
Bombay	Bhartiya vidya Bhavan
Shirur	Vhandmal Tarachand Bora College
Beed (Ambajogai)	Dasopant Samsodhan Mandal
Pune	Deccan College Post Graduate & Research Institute
Nasik	HPT Arts & RYK Science College
Thane	Institute for Oriental studies
Dhule	IBK Rajwade Samsodhan Mandal
Mumbai	KR Cama Oriental Institute
Amravati	Sri Samrthi Vagdevata Mandir
Dhule	Sri Samarthi Vagdevata Mandir
Mumbai	Asiatic Society of Bombay
Nagpur	The Bhonsala Veda Ŝāstra. Mahāvidyalaya
Yeotmal	C P and Berar Jain Research Institute
Mumbai	Forbes Gujarati Sabha, Vithalbhai Patel Rd.
Mumbai	Heras Institute of India History and Culture, St. Xavier's college , Mumbai
Mumbai	Marathi Samsodhan Mandal, marathi grantha Sangrahalaua, Thakurdwar
Karnataka	
Hubli	S.J.M.Math
Dharmashala	Jai Basadi Moodbidri
Mangalagangotri	Mangalore University Library
Bangalore	Central Power Research Institute Library

Dharwar	Karnataka Historical Research Society
Melkote	Academy of Sanskrit Research
Moodbidri	Sri Vira Vani Vilasa Jain Siddhānta Bhawan
Moodbidri	The Danasala Matha Sastra Bhandara
Bangalore	Sri Chamarajendra Sanskrit College Chamrajpeth Sri Siddhanlingeswer Sanskrit
Tumkur	
Melkote, Pandavapura	Sanskrit College, Manday
Mysore	The Parakala Mutt Library
Udipi	M G M College
Udipi	Mutt of Sri Madhvacharya Sansthan
Karkala	Jaina Mutt
Udipi	Sri Kṛṣṇa Mutt
Udipi	The Pejawar Mutt
Mysore	The Palace Sarasvati Bhandar, Mahā. Skt Coll.
Śrāvaṇavelagola	Srimaccarukirti Panditacarya Jain Bhandar
Sringeri	The Sharada Pitha. The Mutt H.H. Swami
Sringeri	Sankara Nārāyaṇa Jyautisika
Bangalore	Kannada Sahitya Parishat
Mysore	Mahāraja Sanskrit College
Mysore	Mysore Sanskrit Academy
Udupi	S M S P Sanskrit College
Melkote	Vedavedantebodhini Sanskrit College Karnataka University, Dept. of Skt, History
Dharwar	
Gulbarga	Institute of Kannada Studies (Gulbara University)
Dharwar	Institute of Kanada Studies (University of Karnataka)
Bangalore	Bangalore University Library
Bangalore	Kalpataru Research Academy
Dharmasthala	Sri Manjunatheswar Cultural & Research Institute
Dharwar	Vidyadhisha Sanskrit manuscript Library
Mysore	Oriental Research Institute
Bangalore	United Theological College

KERALA	
Kāladi	Kāladi Museum & H R B
Trivandrum	O. R. I & Messs. Library
Trivandrum	The state Archives of Kerala
Tripunithura	Sri Ram Verma Govt. Skt. College
Cochin	Central Inst. of Fisheries Techno. Library
Trichur	Rama Verma Research Institute, Town Hall
Kasaragod	Edneermath
Kottayam	Kottayam Public Library Manuscript Library (Dept., of Malayalam) University of Calicut
Calicut	
Calicut	Calicut University Library
Palghat	Chandraprabha Digambara Jain Basti

Thiruvanantapuram	Kerala Granthasala Sandham
Palghat	Palghat educational & Cultural Council
New Delhi	National Archives
New Delhi	Indian Council of Cultural Relation, Azad Bhawan.
New Delhi	National Museum
Delhi	Delhi Archives
New Delhi	Delhi University Library
New Delhi	ICSSR, Social Science Documentation Centre
New Delhi	Indian Institute of Islamic Studies Raja Rammohan Roy National Educational Resources Centre
Delhi	Mahābīr Jain Pustakālaya
Delhi, Timarpur	Bharatiya Vidya Sansthan (Inst. of Indology)
Delhi	Madarsa Aminiya
New Delhi	Dr. Zakir Husain Library (Jamia Milia Islamia)
New Delhi	International Academy of Indian Culture, Haus Khas Enclave
Alipur, Delhi	Bhogilal Lehrchand Research Institute
Delhi	Dargah hazrat Shah Abul Khair
New Delhi, Nizamuddin	Galib Academy

Andhra Pradesh	
Hyderabad	Andhra Pradesh Govt. Oriental Mss. Lib. and Research Institute
Tirupati	Sri Venkateswar oriental REs. Institute
Hyderabad	SVK: Sundarayya Vignana Kendram (Hyderabad ,India)
Hyderabad	Salar jung Museum Library
Hyderabad	Kutub Khana-I-Saidiya
Hyderabad	Jamia Nizamia
Hyderabad	Abul Kalam Azad Oriental Res. Institute
Hyderabad	Archival Cell (Dept. of History
Hyderabad	Birla Archaeological and Cultural Res. Inst
Hyderabad	City Central Library
Hyderabad	Osmania University Regional Library
Rajahmundry	Sri Gowthami Regional Library
Rajahmundry	Sri Rallabandhi Subbarao Archaeological Museum
Viŝākhāpatnam	Andhra University Library, Dr. V S Krishna Library
Rajahmundry	Andhra Historical Research Society

Viśākhāpatnam	Arsha Library
Hyderabad	Oriental Public Bureau and Dairat Ul Mārif
Chitoor	Samskrita Bhasha Pracharini Sabha
Kakinada (Ramraspet)	Telugu Academy
Hyderabad	Sanskrit Academy, Osmania University
Hyderabad	Henry Martyn Institute of Islamic Studies
Hyderabad	The state Archives of Andhra Pradesh
Hyderabad	Archival Cell (Dept. of History

Bhattanavalli	**The sanskrit press and Publications**
Aukiripalli, Kṛṣṇa	Sri Markandeya Sanskrit College
Guntur	Sri Sharada Niketanam
Vijayanagaram	Mahāraja's Govt. Sanskrit College
Nellore	Veda and Sanskrit College
Tirumala	T T D Veda Pathashala
Vetapalem	Saraswata Niketan
Vizianagaram	The Vizianagaram Fort

TABLE 2 DIRECTORY OF VEDIC / INDOLOGICAL/ SANSKRIT UNIVERSITIES & INSTITUTES

There may be some overlap between this table and the previous one

1)Vijnana Bharati, (Swadeshi Science Movement Of India, " Swadeshi Sadan", Guru Narayan Vidya Vihar, Sivasankara .Block, 4th Cross, (Byanna Layout-1st Cross), Nagenahalli Road, Hebbal, Bangalore-560 024 , . E-Mail: Vasu@Vijnanabharti.Com

2) Shri Veda Bharathi,H.NO. H-34, Madhuranagar, HYDERABAD-500 038,Tel,/ Fax: 040-23812577, E-Mail: vedabharathi@sify.com .

3) Sri Aurobindo Kapali Sastry Institute Of Vedic Culture,# 64,13th Main, 4th Bloch East, Jayanagar, Bangalore-560 011. saksivc@zeeaccess.com,infor@vedah.com : www.vedah.org

4) Vedic Vijnana Gurukulam [Dr. Ramachandra Bhat (Kotamane), Principal], Janaseva Trust, Chennanahalli,Kadabagare, Bangalore—562 130

5) Vishva Bharati Research Institute, (Dr. Kapiladev Dwivedi), Gyanpur (varanashi), UP

6) Institute For Studies In Vedic Sciences, Shivpuri, Akkalkot - 413 216, Mahāraṣtra

7) Chinmaya International Foundation, Adi Sankara Nilayam, Veliyanad, Ernakulam District, Pin - 682 319, Kerala, India.

8) Indian Institute Of Scientific Heritage, Thiruvananthapuram, Kerala- 695018.

9) Shree Yogiraj Veda Vighyan Ashram, Kasarwadi, BARSI, District Solapur, Mahārastra-413 401.

10) Harihara Veda Vidhya Peetham, Vedic educational soc., C/o shri M.S.Avadhani, Srinagar colony, Kothagudem, AP. 507 101
11) Institute Of Vedic Sciences, Mrs. MINAKSHI PURI, (For correspondence course in Vedic mathematics)Convener, Spiritual Study Group, 41/2 Amod Kunj,University Campus, ROORKEE-247667
12) The Bhaktivedanta Institute, Vedanta And Science Educational Research Foundation, RC/8,Manasi Manzil Building, 4th Floor, Raghunathpur, V.I.P Road, KOLKATA –700059,Email:bsds@cal.vsnl.net.in
13) Institute Of Vedic Astrology (Director: Ashish Patidar), 1758, Sector-D, Sudama Nagar, Indore-452009, Ph.0731-4076612-13, Fax:4076613;Email: admissions@ivaindia.com, www.ivaindia.com
14) Kashyapa veda research foundation, Shree Kanteshwara Temple Complex, 2nd Floor, Mavoor Road, Calicut- 673004 KERALA. Ph: 0495-4013599; Mo: +919387941136, 9895559134.
15) Ved Vighyan Mahāvidhya Peetha, 21st Km, Kanakpura Road, Udayapura P.O., BANGALORE- 560082 Ph:080-28432273/74; www.srisriayurved.com
16) Indian foundation for vedic science, 1051, Sector-1 Rohtak- 124001. HARYANA
17) Sandipani Vidyaniketan, Mahārshi Sandipani Marg, Porbandar-360 578 Gujarat. Bsstpbr@Sandipani.Org Ph: 0286-222291;
18) Sandipani Vidyaniketan, 4A, Sundarvan, 371, S.V.Road, Vile Parle (west), MUMBAI- 400 056
19) INSTITUTE OF SCIENTIFIC RESEARCH On VEDAS (I-SERVE), Sri Janardananda Sarasvati Jnana Mandiram,11-13-279, Road No.8, Alkapuri, HYDERABAD- 500 035 ANDRA PRADESH. www.serveveda.org
20) Sri Vedic Prathisthan, 158, Gautam Nagar, Nai Delhi- 110 049
21) Dayananda Sansthan, 2286, Ārya Samaj Marg, Karol Baug, Nai Delhi- 110 005
22) Sandipani Himalaya, Siddhabadii, Distt- Kangra 1760 57 HIMACHAL PRADESH, Ph: 01892-2343245, ctthm@sancharnet.in
23) Svädhyaya Mandal, Killa Pardi, Valsad, GUJARAT. Ph: 0260-2373346, 2375888
24) International Vedanta Society, Headquarter - Amingaon, Guwahati-781031, Assam, India.
25) VEDSRI (Regd.) (Vedic Science Research Institute making Vedic Science real) "Vedasram" 5/1 Titan Township, Hosur, Karnataka state, Pin: 635110. Ph:04344-262424 Cell: 9443195667
26) Spiritual Science Research Foundation (SSRF) wholisticnet@gmail.com, http://www.spiritualresearchfoundation.org/
27) Association Of Vedic Sciences (Avs),Sibřina 170,Prague East, Czech Republic 250 84 vedic.sciences@yahoo.com http://www.vedic-sciences.com
28) National Institute Of Vedic Sciences,No.58, Raghavendra Colony, Chamrajpeth, Bangalore – 560018; Tel: 080 - 26675639 Mobile: +91 99426 48154, +91 99720 32471; Email - hblNārāyana@yahoo.com, gaycha20022002@yahoo.co.in, website: http://nivsc.org
29)Mahāriṣi Vedic University, Http://Www.Mahārishi Vedic University.Org/
Mahārishi Mahesh Yogi Vedic Viśvavidyālaya's, Http://Www.Mahārishi-India.Org/Institutions/I3/
30) Dev Sanskriti Viśvavidyālaya, Shantikunj- Gayatri Kunj, Hardwar- 249 411. Tel: 01334-261367, 262094. Http://Www.Dsvv.Org/
31) International Vedic Hindu University, (Formerly Hindu University Of America), 113 N, Econolockhatchee Trail, Orlando, Florida- 32825 Usa Phone Number: 407-275-0013; Fax Number: 407-275-0104. Email : Staff@Ivhu.Edu Www.Ivhu.Edu
32)SVyāsa University, Http://Www.SVyāsa.Org/
Gujarat Ayurveda University. Chanakya Bhavan, Jamnagar- 361 008, (Gujarat) India. Http://Www.Ayurveduniversity.Com
33) Sri Venkateswara Vedic University, Tirupati, Andhra Pradesh
34)Bhandarkar Oriental Research Institute, Pune - 411 001
35) Mahārshi Sandipini Rashtriya Veda Vidhya Prathisthan, Pradhikaran Bhavan, (B-Wing Second Floor), Bharatpuri, Ujjain-456010. Madhya Pradesh.

36) Vaidik Samsodhan Mandal Pune - 411 001
37) Vishveshwaranand Institute And Sanskrit And Indological Studies, Punjab University, Hoshiarpur - 146 001
38) Mahārishi Academy Of Vedic Sciences, Ahmedabad, Gujarat.
39) L.D. Institute Of Indology, Ahmedabad, Gujarat - 380 001
40) Baroda Sanskrit Mahāvidyalaya, Baroda, Gujarat
41) Oriental Institute, Baroda, Gujarat
42) B.J. Institute Of Learning And Research, Ahmedabad, Gujarat - 380 001
43) Dwarkadhesh Sanskrit Academy And Indological Research Institute,Dwarka-361335 Gujarat

APPENDIX J
ASTRONOMICAL (OPTICAL) OBSERVATORIES IN INDIA

The following astronomical observatories have varying quantities of manuscripts related to ancient astronomy in India. Source http://www.cs.utexas.edu/users/mitra/astro.html

STONE OBSERVATORIES OF JAI SINGH

Sawai Jai Singh (1686-1743) constructed five observatories in India at Delhi, Jaipur, Varanasi, Ujjain, and Mathura. He was presumably influenced by the work of Nasiruddin al Tūsi who was Director of the famous al Maragha Observatory during the reign of Hulagu Khan (Grandson of Ghenghiz Khan). See for instance Chapter VIII, Table 6.

The one in Mathura no longer exists. The observatories in Varanasi and Ujjain are in a state of disrepair. In these observatories Jai Singh installed astronomical instruments of pre-telescopic era. Some of the instruments were made out of metal but most were constructed of masonry. Many of the instruments were Jai Singh's own invention such as Jai Prakasa Yantra, Rama Yantra, and Samrat Yantra. Jai Singh was aware of the existence of telescopes but the ones that came into his hands were poor in quality, suffering from defects like spherical and chromatic aberrations. He opted for instruments made out of stone and masonry. Jai Singh produced a set of astronomical tables completed sometime between 1727 and 1735. The tables were called ZIJ-I MUHAMMAD SHAHI - the astronomical tables of Muhammad Shah, the reigning monarch at that time.

THE OLD MADRAS OBSERVATORY

The Observatory was established by the East India Company in 1792. The guiding force behind the construction of this observatory was Michael Topping a sailor-astronomer. He acquired several astronomical instruments, some from William Petrie a noted English astronomer. Among the instruments that he had were achromatic refractors, astronomical clocks with compound pendulum, and an excellent transit instrument. The observing program included stars, the Moon, and eclipses of Jupiter's satellites. For more than a century measurements of stellar positions and brightness's were made. During this period several Government astronomers headed the observatory. Notable among them were Goldingham, Taylor, Jacob, and Pogson. The last astronomer was well known for the Pogson's scale in photometric work. At the end of the nineteenth century the Kodaikanal observatory was constructed which subsumed the role of the Madras observatory. From then onwards the Madras observatory had a side role in weather forecasting and time service.

CALCUTTA

A small observatory was established in Calcutta by the East India Company around 1825 to serve the Survey Department. It had a transit telescope, alit-azimuth circle and later an astronomical telescope was added. Some astronomical observations were performed of Lunar transits and eclipses of Jupiter's satellites, but mostly it was confined to routine time recording and meteorological observations.

LUCKNOW

Nawab Nasiruddin Haydar, who reigned in Oudh, established an observatory in Lucknow during 1832. According to some reports it was one of the best equipped observatories in India at that time. It had a mural circle, a transit telescope, an equatorial telescope, and astronomical clocks. Maj. Richard Wilcox was in charge of the observing program. Wilcox and his assistants observed the major planets, the larger asteroids like Ceres and Vesta eclipses of Jupiter's satellites, occultation of stars by the Moon, and meridional transit of stars. After Wilcox's death the observatory was closed due to political reasons and was destroyed during the Indian War of Independence in 1857.

THIRUVANANTHAPURAM

In 1836, the Raja of Travancore had an observatory built in Trivandrum. He appointed John Caldecott as its director. Caldecott acquired a transit instrument, two mural circles, an equatorial telescope, and magnetic and meteorological instruments. He collected an enormous amount of astronomical data, which included the observations and computations of the orbital elements of the comets of 1843 and 1845. After Caldecott's death the next notable director was John Broun. But Broun's interest was mainly in meteorology and terrestrial magnetism. Broun is associated with the discovery of the relationship between solar activity and subsequent changes in terrestrial magnetism. After Broun's departure in 1865 the observatory was closed by the then Raja of Travancore.

PUNE

Owing to the efforts of a Parsi physicist, K. D. Naegamvala, an observatory was established in Puné around 1882 through a grant from the Mahāraja of Bhavnagar. The observatory had a 20inch Grubb reflector for both visual and photographic work, spectroscopes, and sidereal clocks. It was a premier spectroscopic observatory in India. Naegamvala made spectroscopic observations of the Solar chromosphere and corona during the Solar eclipse of 1898. He also made spectroscopic studies of the Orion nebula and Sunspot groups. After Naegamvala's retirement in 1912 the observatory was dismantled and the instruments were transferred to the fledgling observatory in Kodaikanal. It is fitting that Pune is now the home of the Inter-University Centre for Astronomy and Astrophysics, Pūne, India where the statue of Āryabhaţa ponders benignly on what he has wrought more than 15 centuries ago.

FIGURE 1 ARYABHATA'S STATUE AT IUCAA, PŪNE



CALCUTTA

In 1875, Father Lafont established a spectroscopic laboratory in St. Xavier's College, Calcutta in order to carry out Solar and stellar spectroscopic work. The observatory had equatorial telescopes, transit instruments, and spectroscopes.

Observations of Solar prominences were carried out regularly. Later the focus of the observatory was shifted to meteorological work. Currently, the observatory is being used only for teaching purposes.
Mention must also be made of the observatory in Presidency College, Calcutta. It was constructed in 1900 through a grant from the Mahāraja of Tipperah who donated a 4.5-inch Grubb reflector. In 1922 it received as a gift from the Astronomical Society of India an 8-inch telescope.

INDIAN ASTRONOMY IN THE EARLY 20TH CENTURY

After the Madras famine of 1886-87, an inquiry commission appointed by the Government recommended that the relation between Sunspot activity and the distribution of rains be studied. The site for a solar observatory was selected in Kodaikanal and the observatory started functioning from 1900. Observations of Sunspots, Solar prominences, and Solar photography were carried out on a regular basis from the following year. Spectroscopic instruments were acquired to obtain the spectra of Sunspots and spectro-heliographs of the Sun in the lines of ionized calcium and hydrogen. The Kodaikanal and Madras Observatory had the same director. Over the years the role of the Madras Observatory was confined to the measurement of time, but the observations of the Sun still continue at the Kodaikanal Observatory.

John Evershed became the director of the Kodaikanal Observatory in 1911. He started a program of photographing Solar prominences and Sunspot spectra. He noticed that many of the Fraunhofer lines in the Sunspot spectra were shifted to the red. He showed that these shifts were Doppler. This discovery came to be known as the Evershed effect. From the nature of the Sunspot spectra Evershed concluded that they were similar to stars of spectral type K.

Another discovery of Evershed bears mentioning. While comparing the spectra of the limb of the Sun with that obtained from the center of the disk he noticed a shift towards the red at the limb. He first attributed that to motion but when Einstein's gravitational displacement was considered to be a factor, Evershed recomputed his results. His conclusion was that while Einstein's gravitational displacement could account for most of the shift, there still remained a definite unexplained residual shift.

HYDERABAD

A wealthy nobleman in Hyderabad acquired a 15-inch Grubb refractor and established an observatory at Begumpet, Hyderabad. The observatory was taken over by the Nizam's Government in 1908 and it soon became involved in an international program of mapping the sky. In this carte-du-ciel program 18 observatories with similar instruments took part. For this program an 8-inch astrograph was acquired. The observatory was allotted the zone between declinations -17° to -23°. Later it also covered the zone between declinations +39° to +36°, originally given to Potsdam. The observations were carried out by fewer than 3 directors - Chatwood, Pocock, and Bhāskaran. Twelve catalogues containing 800,000 stars were published.

T. P. Bhāskaran also started an observing program of variable stars with the 15-inch Grubb telescope. It was during his time that control of the observatory passed from the Nizam's Government to Osmania University. Akbar Ali succeeded Bhāskaran in 1944. Ali started a program of double star measurement. He felt the need to introduce the new study of photoelectric photometry and placed an order for a 48-inch telescope for the observatory.

The Nizamiah Observatory, which had 15-inch refractor and an 8-inch astrograph, was under the administration of Osmania University. In 1959 a separate teaching department was started in 1964. The

University Grants Commission recognized the department and its observing facilities as a Centre for Advanced Study in Astronomy. A 48-inch telescope was commissioned in 1968 and installed near the villages of Japal and Rangapur. The center under the directorship of K. D. Abhyankar had an active program in photoelectric photometry and spectroscopic observations of variable stars.

In the first half of the twentieth century most of the observational work was being conducted at Kodiakanal and Nizamiah Observatories. Much of the theoretical work was being done at three centers - Calcutta University, Allahabad University, and Varanasi Hindu University.



FIGURE 2 NAINI TAL OBSERVATORY

At Calcutta University, Prof. C. V. Raman attracted a bright group of young physicists. Among them was M. N. Saha. Saha's greatest contribution was in the theory of thermal ionization and its application to stellar atmospheres. Saha moved to Allahabad University and started a strong group on theoretical astrophysics. Several members of this group made important contributions in the field of stellar interiors. Another group inspired by V. V. Narlikar worked on cosmology at the Varanasi Hindu University. His son J. V. Narlikar carried on this line of research.

POST INDEPENDENCE OPTICAL ASTRONOMY IN INDIA

The main centers for optical astronomy in India areIndian Institute of Astrophysics at Bangalore, Center for Advanced Study in Astronomy at Osmania University, Uttar Pradesh State Observatory at Naini Tal, and Physical Research Laboratory at Ahmedabad.

KODAIKANAL

In 1971 the old Madras and Kodaikanal Observatory were made into a single autonomous research institution. The Solar observations continued to be performed at Kodaikanal. New instruments had been added over the years - a large solar telescope with a high dispersion spectrograph, a coronagraph, and a monochromatic heliograph. The Solar telescope now has a photoelectric magnetograph to make fine measurements of magnetic and velocity fields in the Sun. This observatory has sent out several expeditions to observe solar eclipses.

Optical observations of stars and galaxies are conducted from Kavalur in Tamil Nadu. The 20inch Grubb reflector that was acquired from the Mahāraja Takhtasingji Observatory was transferred from Kodaikanal to Kavalur. After Bappu became the director a 30-inch reflector was added to the observatory for photoelectric photometry. During Bappu's directorship a 2.3 meter telescope was designed and fabricated indigeneously. This telescope is used at prime (f/3.25) and cassegrain (f/13) foci for imaging and medium resolution spectroscopy using CCD detectors. There is also a 1-meter Carl Zeiss telescope used for CCD imaging and low resolution spectroscopy.

The government of Uttar Pradesh established an observatory in 1954 at Varanasi. It was later shifted to Naini Tal. The observatory also has a 15 inch and a 20-inch reflector with folded Cassegrain and Coude

foci for Solar work. The observing program includes photoelectric photometry of variable stars, comets, and occultation work. In 1977, during the occultation of SAO158687 by Uranus, observers at Naini Tal detected the ring system around this planet.

The 50-year old State Observatory at Naini Tal was reincarnated on 22nd March 2004 as ARIES, an acronym given for Āryabhaţa Research Institute of Observational-Sciences, an autonomous institute under the Department of Science and Technology, Govt. of India. Historically. The Observatory came into existence at Vāranasi on 20th April, 1954. The Observatory was later moved from the dust and haze of the plains to more transparent skies of Naini Tal in 1955, and to its present location in 1961 at an altitude of 1951m at Manora peak, a few km south of the Naini Tal town.

MOUNT ABU

There is a 48-inch telescope at Gurushikhar on Mt. Abu. The telescope is operated by the Physical Research Laboratory (PRL) and is used mainly for infrared work. They have a 256 x 256 pixel HgCd array detector for 2 micron imaging. The observing program includes spectroscopy and polarimetry. PRL also has a solar observatory in Udaipur. It has a 12-ft solar telescope on a small island in the midst of Fateh Sagar Lake. The observatory is involved in high resolution chromospheric and photospheric studies of flares.

APPENDIX K RESOURCES FOR SANSKRIT MANUSCRIPTS OUTSIDE INDIA

SANSKRIT MANUSCRIPTS OUTSIDE INDIA

British Library, London
Bendall, C, Catalogue of the Sanskrit manuscripts in the British Museum... London, 1902. Losty, J, Catalogue of Sanskrit and Prakrit manuscripts in the British Museum vol. II... Unpublished typescript. Classed inventory Manuscript register in 2 volumes kept in OIOC Reading Room at Or Gen MSS 15
Eggeling, J., Keith, AB, and Thomas, FW. Catalogue of the Sanskrit and Prakrit manuscripts in the Library of the India Office. London, 1887-1935. 2 volumes, contains for example

Āryabhaţīya in Malayālam
BijaGaṇita and Lilāvati in Telugu
Āryabhaţīya Sūtrabhāshya by Bhāskarāch Ārya I
Karanakutuhala
Mahāvirācharya's Ganitasārasangraha (1800)
Narasimha's Siddhānta Siromani Vāsana Varttika (1800) (Goladhyāya)
Bha Swāti of Satananda
Gaṇitasara of Sridharacharya
Sūrya Siddhānta and many others
Supplementary Catalog of Sanskrit, Pali, and Prakrit Books.

Tawney, CH, and Thomas, FW. , London, 1903. Catalogue of two collections of Sanskrit manuscripts preserved in the India Office Library.
Nevill, H, Catalogue of the Nevill Collection. Unpublished manuscript. 4 vols.
Barnett, L.D. *List of Pali, Sinhalese, S* 1909.
Somadasa, K.D., Catalogue of the Hugh Nevill Collection of Sinhalese manuscripts in the British Library. London, 1987-95. 7 vols.
Raper, T.C.H., ed., and O'Keefe, M.J.C., rev. Catalogue of the Pall printed books In the India Office Library. London, 1983.
Ancient Buddhist Scrolls from Gandhara: the British Library Kharosthl fragments. Sanskrit and other manuscripts, formerly In the possession of Hugh Nevill Esq. Salomon, R. London, Seattle, 1999. Preliminary list of manuscripts in languages of Central Asia and Sanskrit, from the Collections made by Sir Marc Aurel Stein, KCIE.
Barnett, L.D. Unpublished typescript
Gaur, A, Indian charters on copper plates. London, 1975.
Haas, E, Bendall, C, and Barnett, LD, Catalogue of Sanskrit, Pali, and Prakrit Printed Books in the British Museum. London, 1876-1928, 4 volumes
Natha, P., Chaudhuri, J.B., and Na pier, C.F. Catalogue of the Library of the India Office. vol. 2, part 1: Sanskrit books. London, 1938-57.4 vols.

Shaw, G.W. and Quraishi, S. Bibliography of South Asian periodicals: a union-list of periodicals in South Asian languages. Brighton, 1982.
Bodlean Library, Oxford
British Library Oriental & India Office Collections Has one of the largest collections of Sanskrit texts outside of India

The École francaise d’Extréme-Orient (EFEO) is a French institute dedicated to the study of Asian societies. Translated into English, it approximately means the French School of the Far East. It was founded in 1900 to study the civilization of Saigon (now Ho Chi Minh City) in what was then French Indochina, with a branch in Pondicherry India. It is headquartered now in Paris. The main fields of research are archaeology and the study of modern Asian societies.

École Française d’Extrême-Orient (EFEO), 22, avenue du Président Wilson ,75116 PARIS tél. 01 53.70.18.60, fax 0 1.53.70.87.60, *http://www.efeo.fr/contacts/paris.shtml*

Cambridge University Centre of South Asian Studies

The Library of Trinity College, Cambridge

Cleveland Public Library

Columbia University

Listing of http://www.columbia.edu/cu/lweb/indiv/southasia/cuvl/LIBS.htm

COPAC

(A union catalog of British Research Libraries, including Cambridge Univ., Edinburgh Univ., Glasgow Univ., Leeds Univ., and Oxford Univ.)

Cornell University

Harvard University

Leiden University (Netherlands)

Library of Congress, Southern Asia Section

LC Field Office New Delhi

National Archives of India

NAI home page

User's Guide to the National Archives of India (Richard White, Univ. of Wales, via H-ASIA)

National Library of Australia

National Library of Bhutan

National Library of Scotland

India Papers collection

Medical History of British India

New York Public Library

Oxford University

School of Oriental & African Studies - SOAS (University of London)

South Asia Resources Database: The Australian Union Catalogue of South Asian Library Resources (via Curtin University) (About 250,000 indexed bibliographic records from two files: main file of South Asia holdings in Australian libraries, and MARC records from National Library of Australia which don't have Australian locations. Site includes simple search as well as advanced boolean searching capabilities.)

University of British Columbia

University of California - Berkeley

University of Chicago

University of Groningen (Netherlands)

University of Hawaii at Manoa

University of Heidelberg - South Asia Institute Library

Universitats Bibliothek zu Leipzig, Theodore Aufrecht

University of Michigan Libraries

University of Minnesota, Ames Library of South Asia

University of Pennsylvania

University of Texas, Austin

University of Toronto

University of Virginia
University of Washington
University of Wisconsin - Madison
The Wellcome Library, London
Verzeichnisse der Sanskrit Handschriften von Weber, Berlin
World Association of Vedic Studies (WAVES), America. Http://Www.Wavesinternational.Net
European Academy of Vedic Science- Info@Veda-Academy.Com Www.Vedic-Academy.Com/
Florida Vedic College, America Http://Www.Floridavediccollege.Edu
American Institute of Vedic Sciences, Http://Www.Vedanet.Com
Sierra Center of Vedic Sciences, California. Http://Www.Sierravedic.Com/
Vedic Educational and Devotional Academy (Veda), 46919, Fernald Common, Fremont, Ca 94539 USA
Belarusian Vedic Academy, Mikhail Ivanovich Mikhailov, Director, 11-36 Yakubovskogo. Gorki, Mogilevskaya Obl., 213410 .Email: Mihail@Mogilev.By.
International Gita Society, USA Http://Www.Indiadivine.Org/
The World Community For Indian Culture And Traditional Disciplines,
Italy, www.Theworldcommunity.Com
European Yoga Federation, Www.Europeanyogafederation.Net

APPENDIX L
COMPARATIVE TIMELINE OF GREECE, SOUTH & WEST ASIA

TABLE 1 COMPARISON OF TIMELINE OF ANCIENT GREECE WITH KEY EVENTS IN PERSIA, BABYLONIA AND INDIA

ALL DATES ARE BCE UNLESS OTHERWISE STATED GREGORIAN YEAR	
8000	Beginning of river valley civilizations
7000-3300	Greece, Neolithic Period
7000-4000	The Vedic Era. 27/28 Nakṣatras already identified
	First wave of emigration , after the Dasarajna war, the Druhyus (Dāryavāhyu) and The Yavanas (transformed into the Ionians after 1 to 2 millennia)
3100	The era of the MBH. The drying of the Sarasvati is well under way by this time and is completely desiccated by 2000 BCE
3300-1050	Bronze Age
2200-1500	Minoan palaces established on Crete
2500	Second wave of Emigrants from the Sarasvati Sindhu civilization. possible ancestors of the Kassites
2200-1300	The Vedāṅga Era Establishment of computational astronomy. Major parameters of Indian calendar are in place
1600	Rise of Mycenaean's
1400	The Hittite Mitanni treaty invokes the Vedic deities Nasatyas, Varuna and Mitra
1400-1200	Mycenaean's conquered Crete
1200-1000	beads and ornaments made out of glass by Mycenaean's
1184	Dorians invaded Greek mainland
1066	traditional date for the destruction of Troy
900	Position of Archon replaced the king in Athens
1050-750	Greek Dark Age
900	Pre-Siddhāntic Era in Indian astronomy Jaina astronomy makes significant advances Era of Homer
875-750	founding of Sparta
776	geometric period in pottery

753	first Olympic Games
753	traditional date for the founding of Rome
752	archon position limited to ten years in Athens
750-500	Archaic Age
730-710	Spartans conquered Messenia
	Thales of Miletus observes the first recorded Eclipse in Greece
683	archon position in Athens changed from one to nine, elected every year
669	Sparta defeated by Argos
	HAXAMANISH or ACHAEMENES, first King of Persia,
654 642	Hesiods works and days
650	first life-size marble statue created
650-600	first bronze statues made by lost wax method
650	TEISPES, King of Persia c. 7th century BC.
640	KURASH I (or CYRUS I) c. late 7th Century BC, son of Teispes.
630	ARIARAMNES c. late 7th century BC, son of Teispes
620	Draco's harsh laws instituted in Athens
594	Solon became archon and began democratic reforms in Athens
560	Peisistratus's tyranny begins in Athens
559	KAMBUJIA I (or CAMBYSES I)? - 559 BC, son of Kurash I.
556	Peisistratus forced to leave Athens by opponents
556	KURASH II (or CYRUS II) 559 - 550 BCE when he became King of Kings ", Shahanshah 550 - 529 BCE, son of Kambujia. . Cyrus united Iranian territory and took Babylonia and much of Asia Minor into a Persian Empire.
559-525 **529 – 525**	Kambujia II (or CAMBYSES II) 529 - 522 BC, added Egypt to the Empire.
522 **522-486**	BARIYA March - Autumn 522 BC, brother of Kambujia II. Dāryavāhyu or Dāryavāhyush I (or DARIUS I) autumn 522 - Nov. 486 BC, great-grandson of Ariaramnes, extended the empire east to the Indus and tried to take

	Greece where he was defeated at Marathon in August 490 BC.
486-465	Xshayarshan OR Akṣayarshan(Greek Xerxes) became king of Persia,, son of Dāryavāhyush I. He tried again to take Greece but after the victory at Thermopylae was defeated at Salamis in 480 BC.
481	Persians defeated the Spartans at Thermopylae
480	Persians defeated at naval battle of Salamis
480	Persians forced to withdraw from Greece
478	Delian League under Athenian leadership formed
476	naval campaign by Cimon began for Athens and continued for next three years
471	Themistocles ostracized from Athens
467	Persians defeated by Cimon
463	Cimon prosecuted by Pericles, but acquitted in Athens
462	democratic reforms by Pericles in Athens
461	Cimon ostracized from Athens
460-446	first Peloponnesian War
431-404	second Peloponnesian War
430	plague in Athens
429	death of Pericles
405	Athenian navy badly defeated by Lysander at battle of Aegospotami
404	surrender of Athens Oligarchy of Thirty appointed by Sparta (nicknamed the “Thirty Tyrants”)
403	fall of Thirty Tyrants democracy returned to Athens
399	Socrates condemned to death
387	Plato founded Academy in Athens
359	Phillip II became king of Macedonia
358-336	Phillip’s empire expanded into other territories and defeated the Greek city-states
336	Darayavahyu (Greek Darius III) became king of Persia
336	Phillip II assassinated; Alexander the Great took over throne
334	Alexander defeated Persians at Granicus River
333	Alexander defeated Darayavahyu III at Issus
332	Alexander entered Egypt
331	Alexander established Alexandria

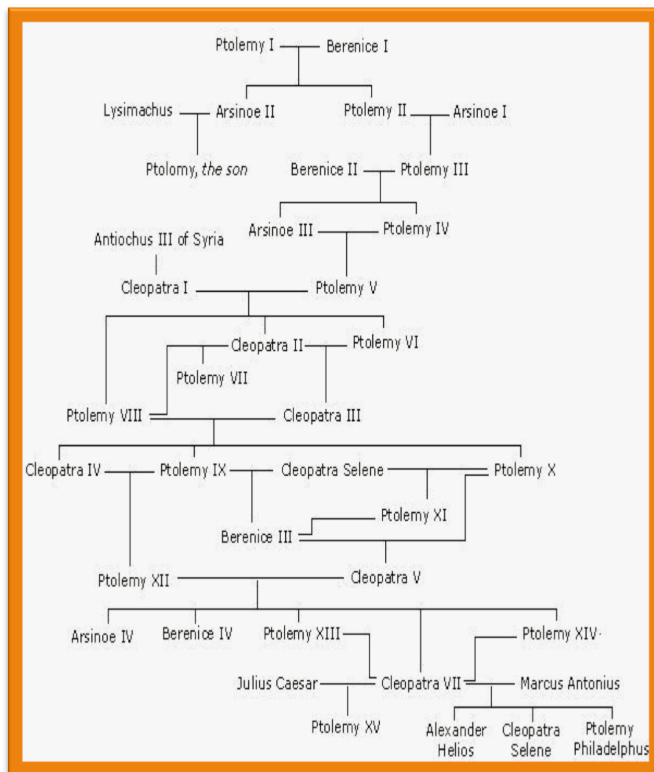
331	Alexander defeated Darius III and Persians at Gaugamela
326	Alexander battled Purusottama inconclusively, at the Kshatrapy of Punjab at Hyphasis River in India. It is Purusottama who spares his life and not the other way around. Besides, we are not aware of a single instance of Alexander sparing the life of a defeated rival. It would have been totally out of character. The story of Alexander turning back because of mutinous rebellion amongst his troops seems highly farfetched. These were battle hardened soldiers, who did what they were told. Many in fact were mercenaries. The notion that his original band of Macedonians, with the exception of a small band of cronies, was still with him after 8 years of continuous warfare doesn't appear realistic The reality is that he was defeated by Purusottama, who was a minor Kshatrapy on the borders of the Magadha Empire. The last of the Sātavāhanas was ruling India at that time. The wealth of India was his for the taking if the conventional accounts were true. It must be noted that the accounts of Alexander exploits are all second hand and neither Strabo nor Arian, who wrote about Alexander at least 300 years after his death, believed in the credibility of the cronies of Alexander Onesecritos, Nearchus and Ptolemy who were the only witnesses to have left an account of Alexander's putative invasion of India. This view is bolstered by the deafening silence in India regarding the details of Alexander's campaign. Why they should omit to mention Alexanders invasion when they faithfully recorded the invasion of the Sakas both before and after Alexander is a question that no historian west of the Bosphorus has satisfactorily answered. The answer appears to be that it was a non-event. But the revisionist historians of the Occident could not stomach the defeat of the only Occidental in the ancient era, to have made inroads into Asia and have embroidered the tale of Alexander into mythic proportions and have made the date of Alexander's unsuccessful campaign in India, the main sheet anchor of Indian History.
322	Alexander died , most likely because of wounds suffered in his Indian battle
323-30	Hellenistic Period
306	Antigonus, Ptolemy, and Seleucus I proclaimed themselves kings over areas of Alexander's empire
250 – 200	Archimedes screw invented
200	screw press for pressing olives and grapes invented
146	parts of Greece became part of Roman Empire
30	All of Greece and Ptolemaic Egypt became part of Roman Empire with the fall of the Ptolemies at the Battle of Actium.

TABLE 2 KINGS OF ASSYRIA AND BABYLON		
Ruler	Ri reigned	Comments
Nabonassar	746 – 732 BCE	
Nabu-mukin-zeri	732 – 729 BCE	
Tiglath-Pileser III	729 – 727 BCE	
Shalmaneser V	727 – 722 BCE	
Marduk-apla-iddina II	722 – 710 BCE	*(the Biblical Merodach-Baladan)*
Sharrukin II (Sargon II)	710 – 705 BCE	
Sin-ahhe-eriba (Sennacherib)	705 – 703 BCE	
Marduk-zakir-shumi II	703 BCE	
Marduk-apla-iddina II	703 BCE	(restored)
Bel-ibni	703 – 700 BCE	
Ashur-nadin-shumi	700 – 694 BCE	*son of Sennacherib*
Nergal-ushezib	694 – 693 BCE	
Mushezib-Marduk	693 – 689 BCE	
ASSYRIAN SACK OF BABYLON, 689 BC; BABYLON IS REBUILT BY ESARHADDON OF ASSYRIA IN THE 670'S BC		
Sin-ahhe-eriba (Sennacherib)	689 – 681 BCE	
Ashur-ahha-iddina (Esarhaddon)	681 – 669 BCE	
Shamash-shum-ukin	668 – 648 BCE	*son of Esarhaddon*
Kandalanu	648 – 627 BCE	
Sin-shumu-lishir	626 BCE	Only parts, including the City of Babylon.
Sinsharishkun	ca. 627 – 620 BCE	Lost control over Babylonia.
Nabu-apla-usur (Nabopolassar)	626 – 605 BCE	
Nabu-kudurri-usur (Nebuchadrezzar II)	605 – 562 BCE	
Amel-Marduk	562 – 560 BCE	
Nergal-shar-usur (Nergal-sharezer/Nerialissar)	560 – 556 BCE	
Labashi-Marduk	556 BCE	
Nabu-na'id (Nabonidus)	556 – 539 BCE	
PERSIAN RULERS OF THE HAKSAMANISH DYNASTY		
Cyrus II of Persia	539 – 529 BCE	
Cambyses II	529 – 522 BCE	son of Cyrus the Great
Smerdis (Bardiya)	522 BCE	(Possibly a usurper) alleged son of Cyrus the Great
Darius I of Persia the Great	521 – 486 BCE	brother-in-law of Smerdis and grandson of Arsames
Xerxes I of Persia	485 – 465 BCE	son of Darius I
Artaxerxes I of Persia Longimanus	465 – 424 BCE	son of Xerxes I

Xerxes II of Persia	424 BCE	son of Artaxerxes I
Sogdianus of Persia	424 – 423 BCE	half-brother and rival of Xerxes II
Darius II of Persia	423 – 405 BC	half-brother and rival of Xerxes
Artaxerxes II of Persia Mnemon	404 – 359 BC (see also Xenophon) son of Darius II	
Artaxerxes III of Persia Ochus	358 – 338 BC	son of Artaxerxes II
Arses of Persia (Artaxerxes IV)	338 – 336 BC	son of Artaxerxes III
Darius III of Persia Codomannus	336 – 330 BC great-	
THE MACEDONIAN DYNASTY, SELEUCIDS AND THE PTOLEMAIC DYNASTY		
Alexander of Macedonia	330-323 BCE	
Alexander IV of Macedon	323 – 309 BCE	
Seleucus I Nicator, Satrap, King	311 – 305 BCE	
***Antiochus I Soter*, co-ruler from 291**	281 – 261 BCE	
Antiochus II Theos	261 – 246 BCE	
Seleucus II Callinicus	246 – 225 BCE	
Seleucus III Ceraunus (or Soter)	225 – 223 BCE	
Antiochus III the Great	223 – 187 BCE	
Seleucus IV Philopator	187 – 175 BCE	
Antiochus IV Epiphanes	175 – 164 BCE	
Antiochus V Eupator	164 – 162 BCE	
Demetrius I Soter	161 – 150 BCE	
Alexander I Balas	150 – 145 BCE	
Demetrius II Nicator	145–141 BCE	
Ptolemy I Soter (303 BC-285 BC)		
Ptolemy II Philadelphus	285 -246 BCE	married Arsinoe I, then Arsinoe II Philadelphus;
Ptolemy III Euergetes BC)	246 BC-221BCE	married Berenice II
Ptolemy IV Philopator BC) married Arsinoe III	221-203 BCE	
Ptolemy V Epiphanes	203 BC-181 BC	married Cleopatra
Ptolemy VI Philometor	181 -164 BCE,	
Ptolemy VIII Eurgetes II	164 – 145 BCE	married Cleopatra II, then Cleopatra III; temporarily expelled from Alexandria
Cleopatra III Philometor Soteira Dikaiosyne Nikephoros (Kokke)	116 - 101 BCE	jointly ruled with Ptolemy IX and Ptolemy X

Berenice III Philopator	81 -80 BCE	
Ptolemy XI Alexander II	80 - 58BCE	
Epiphaneia	58 -55 BCE	
Cleopatra V Tryphaena	58 – 57 BCE	
Cleopatra VII Philopator	51 -30 BC E	ruled jointly with Ptolemy XIII Theos Philopator (51 BC-47 BC),
Egypt becomes part of Roman Empire		

FIGURE 1 PTOLEMAIC RULERS OF EGYPT 323 BCE to 31 BCE, indicating high degree of inbreeding amongst the small community of Macedonian Greeks ruling Egypt



APPENDIX M
PROPOSED CHRONOLOGICAL FRAMEWORK FOR INDIA

TABLE 1 PROPOSED CHRONOLOGICAL FRAMEWORK FOR INDIA **We do not pretend that every date in this table is precise, but we believe that the overall skeleton is far more consistent internally and externally than the current one which is based on the dates of Alexander's Asian Campaign**		
Legend	Individual or detailed description	Date
Geologic event	End of Glaciations	10,000 BCE
Geologic event. We are in the Warming half cycle between glacial eras	Melting of Glaciers. There are believed to be various cycles, shortest being 40,000 years	
Geological Event	Formation of River Valley Civilizations - Cavalli Nori in Anatolia	8000 BCE. It was previously believed that RV civilizations only occurred no earlier than 4000 BCE
Astronomical Observation	Taitiriya Brāhmaṇa, makes reference to Aja Ekapada, the Nakṣatra Pūrva Bhādrapadā, α Pegosi, when the autumnal equinox occurred in this Nakṣatra	11413 BCE
Astronomical Observation	Taittiriyā Saṃhitā places Winter solstice in Plaiedes or Krittika	8948 BCE
ERA. The beginning of recorded History in Oral Traditions. (Srautic Parampara)	The Vedic ERA. The ten mandalas of the Ṛg were composed over a period of 500 years	7000 to 4000 BCE
Era Sarasvati Sindhu Civilization	Mehrgarh Culture, early phase	7000 BCE
War	Dasarajna War, The Battle of the Ten Kings	7000 BCE
Dynasty	The Ikshvakus and the Rāmāyaṇa	6000 BCE
Era , Paradigm shift, a phenomenal efflorescence of knowledge, the Vedic Episteme	Brāhmaṇa Era, Beginning of	5000 BCE
Vedic episteme 27 Nakṣatras named, 12 spokes of the Zodiac		5000 BCE
The RV 3.9.9, RV 10.21(BG Siddharth), R.V 10.52.6 (RN	Postulates a basic vedic unit of 33 years with 371 intercalary days,	5000 BCE

Iyengar Abhyankar, interpretation as related to eclipse cycle. See chapter III	so that in a 9*33 (297 years) there are 3339 intercalary days (3339 Devas worship Agni), 113 synodic months	
The sixty year cycle attributed to Babylon gets mentioned in the Veda	This predates the development in Babylon	
Era	Purāṇic Era	5000 BCE – 3000 BCE
Astronomical observation, R.V 5.40	Earliest eclipse observed in RV PC Sengupta	3928 BCE, July 25
Birth	Veda Vyāsa	3200~3300 BCE
Vedic episteme Yājnavalkya note that this is 1/3 the 297 year cycle	Deduced the 95 year synchronism cycle between the periodicities of the Moon and the earth	3000 BCE
Observation Vernal Equinox in Rohiṇi	Observation of Nakṣatra in which the Vernal Equinox occurs	~3100 BCE
War	The Great Bharata War	Nov 22, 3067 BCE (3101+-36 BCE –error caused by changes in Julian calendar)
Paradigm shift to Likhit Parampara (scriptural as opposed to oral tradition)	Era of the Sulva Sūtras. Sūtras of the cord, development of geometry, trigonometry	4000 ~2000 BCE
Birth	Āpastamba	~3000 BCE
Birth	Baudhāyana	~3200 BCE
Era	Kali Yuga	3101 BCE
Death	Sri Kṛṣṇa Nirvana	3101 CE
Writings , scripts had coalesced into codified symbols	Pingala	2900 BCE
Writings	Pāṇini ’s Ashtādhyāyi, codification of Vyākarana and other Vedāṅgas	2900 BCE
Paradigm shift	Use of Decimal Place Value system (Panini, Pingala). Catalyzed Indic contributions to algebra, number theory, infinite	2900 BCE

	series, spherical trigonometry	
Era Sarasvati Sindhu civilization	Mature Phase	3000 BCE – 1700 BCE
Dynasty (Magadha)	Brihadratha Dynasty (22 kings, 1006 years)	3138 BCE - 2132 BCE
Birth (potential misdating of Āryabhaţa)	Āryabhaţa	2765 BCE ,337 Yugabda, Conventional date of 479 CE is highly suspect
Writings	Yājnavalkya, Brihat-Aranyaka Upanishad, Śatapatha Brāhmaṇa	~3000 BCE Astronomical evidence
Astronomical Observation in Patanjali's Yoga Sūtras, Grihya Sūtras and Maitreyi Upanishad	α Draconis (Thuban) is the Pole star. The Pole star was always referred to as the Dhruva	2800 BCE (345 Yugabda)
Heliacal Rising of α Leonis or Regulus and Summer solstice	Mentioned by W.Brennand	2280 BCE
Dynasty	Pradhyota Dynasty (5 kings, 138 years)	2132 to 1994 BCE
Dynasty	Sisunaga Dynasty (10 kings ,360 years)	1994-1634 BCE
Lifespan	Gautama Buddha	1887-1807 BCE Purāṇic and astronomical evidence
Birth	Mahāvīra	1862 BCE
Extract from Varāha Mihira, date when Vedāṅga Jyotiṣa Composed	Winter Solstice in Dhanishta' assuming Dhanishta is δ capricornus	January 5,1861 BCE
Dynasty	Nanda Dynasty (Mahāpadmananda and his sons)	1634 – 1534 BCE
Coronation	Chandragupta Maurya	1554 BCE -1500 BCE
Coronation	Aṣoka Maurya	1472 BCE
Dynasty	Maurya (12 kings ,316 years	1534-1218 BCE
Extract from Varāha Mihira, date when Vedāṅga Jyotiṣa Composed	Winter Solstice in Dhanishta' assuming Dhanishta is β Delfini	1350 BCE
Dynasty	Kushana Empire	1298 BCE
Coronation	Aṣoka Gonanda	1448 BCE
Coronation	Kanishka	1298 BCE
Dynasty	Sunga Dynasty (10 kings, 300 years)	1218 – 918 BCE
Writings	Patanjali's Mahābhashya	1218 BCE

Writings	Nāgārjuna	1294 BCE
Reign	Kanishka	1298-1237 BCE
Writings	Kālidāsa I	1158 BCE
Dynasty	Kanva Dynasty (4 kings,85 years)	918-833 BCE
Era	Andhra Sātavāhana (32 kings , 506 years)	833 BCE -327 BCE
Birth	Kumārila Bhaṭṭa (Mīmāmsa)	557 BCE
Era (was in use for a short period of time when Kuru controlled the Punjab)	Ṡakanripa Kala (era of Cyrus(Kuru or Kurush) the great of Persia, Jan	550 BCE
Birth	Adi Sankarācharya (has an audience with Hala Sātavāhana)	509 BCE-477 BCE
Famous Babylonian Astronomer. Beginning of computational astronomy in Babylon	Kidinnu or Cidenas. If this is the first instance of a computational astronomer in Babylon, it is indisputable that the Indics have been doing this for several centuries prior to this	500 BCE ?
Harsha Vikramāditya		
Coronation	Alexander of Macedonia	336 BCE
Coronation. The Gupta's were of the Solar dynasty and usually had the name Āditya as a suffix	Chandragupta Vijay Āditya of Gupta dynasty	327 BCE
War. Alexander's incursion into India non-event. It should never have been used as a synchronism or a sheet anchor for India. Another example of Eurocentricity	Alexander initiates an inconclusive battle with Purusottama, regional Kshatrap in the Punjab and is forced to retreat short of his goal of vanquishing the great civilization of India.	326 BCE
Dynasty	Imperial Gupta Dynasty (7 kings, 245 years)	327 BCE-82 BCE
Coronation	Chandragupta Vijay Āditya	327 BCE
Coronation	Samudragupta Aṣoka Āditya Priyadarshin (a lot of the edicts thought to be of Aṣoka Maurya were actually installed by this monarch	320 BCE
Writings	Varāhamihīra Pancha Siddhānta	123 BCE? Other dates (285 CE)

Reign	Vikramāditya	102 BCE to 78 BCE
Era	Vikrama Ṡaka named after Vikramāditya	57 BCE
Writings	Kālidāsa II, author of Raghuvamsa, Jyotirvidabharana	57 BCE
Birth	Brahmagupta	30 BCE
Era	Ṡālivāhana Calendar ((Punwar dynasty)	78 CE
Writings	Bhāskara II, aka Bhāskarāchārya Siddhānta Siromani	486 CE
Dynasty	Punwar Dynasty (23 Kings,1111 years)	82 BCE-1193 CE
Era	Christian Era	0 (Yugabda 3101)
Era	Ṡālivāhana (Ṡaka Calendar))	78 CE
Vernal Equinox first point of AṠvini or Meṣa	'Modern' Sūrya Siddhānta	570 CE
Writings	Huen-Tsang	625 CE
Writings	Kālidāsa III (lived in Bhoja's time)	638 CE
Dynasty	Pala Empire	750-1174 CE
coronation	Bhoja Raja's coronation	648 CE
coronation	Sri Harsha Sail Āditya	648 CE
Dynasty	Chola Empire	848 CE – 1279 CE
Beginning of Islamic Era	Prithviraj Chamahana	1192 CE
Era	Delhi Sultanate	1192 CE – 1526 CE
Era	The Hoysalas	1040 CE–1346 CE
Reconquista begins and the Fall of Toledo	Toledo, the great Muslim center of learning falls into Christian hands	1085 CE
Era	The Kakatiyas	1083 CE–1323 CE
India's first Modern Historian	Kālhāna (Kashmir Historian)	1,148 CE
Era	Bahmani Confederation	1390 CE -1596 CE
Era	Vijayanagar Empire	1339 CE -1625 CE
Era	The Mughal Empire	1526 CE – 1757 CE
Dynasty The Maratha Empire	the last Indic empire prior to conquest by Empire of Britain	1674 CE – 1818 CE
Writings , translations of the Hindu Astronomy & ephemeris	Memoirs of the Academy of Sciences, M La Loubere, re.	1687 CE

Dynasty	The Sikh Confederacy	1716 CE – 1849 CE
Dynasty	The Empire of Britain, The British Royalty were mostly of German ancestry	1757 CE – 1947 CE
Era	The Modern Republic	1950 CE

APPENDIX N
DYNASTIC LISTS OF THE MAGADHA EMPIRES

FROM THE TIME OF THE MAHĀBHĀRATA WAR

TABLE 1 DYNASTIES OF THE MAGADHA EMPIRE

Dynasty	Number of Kings	Period	Total number of years ruled	Cumulative total
Brihadratha	22	3136 to 2132 BCE	1006	
Pradhyota	5	2132 to 1994 BCE	138	1144
Sisunaga	10	1994 to 1634 BCE	360	1504
Nanda	9	1634 to 1534 BCE	100	1604
Maurya	12	1534 to 1218 BCE	316	1920
Sunga	10	1218 to 918 BCE	300	2220
Kunwa	4	918 to 833 BCE	85	2305
Andhra Sātavāhana	33	833 to 327 BCE	506	2811
Imperial Gupta	77	327 to 82 BCE	245	3055
Punwar or Pramara	24	82 BCE to 1193 CE	1275	4330
Totals	206	3136 BCE to 1193 CE	4330	

APPENDIX O
SELECT TOPICS IN ANCIENT INDIAN MATHEMATICS & ASTRONOMY

DECIMAL PLACE VALUE SYSTEM AND THE ZERO
TRIGONOMETRY
PI AND THE SINE TABLE
SPHERICAL GEOMETRY
THE INDIC PENCHANT FOR LARGE NUMBERS
UNITS OF MACRO AND MICRO TIME

The occidental, with some significant exceptions, grudgingly accepts the conventional view that the zero and the decimal place value system was developed by the ancient Indic but is loath to attaching any great significance to it. Most text books still refer to the decimal system as the arabic numeral system and David Pingree went so far as to say that the decimal place value system was a borrowing from Babylon transmitted to India via the Greeks[308].

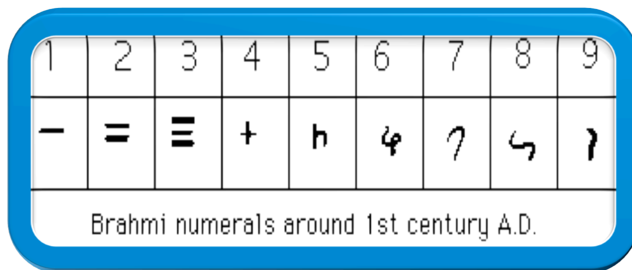


FIGURE 1 BRAHMI NUMERALS

DECIMAL PLACE VALUE SYSTEM AND THE ZERO

The following is a more sympathetic view of what is now regarded as a significant advance in the history of the human species

WHO INVENTED THE ZERO AND WHERE WAS IT INVENTED

The final independent invention of the zero was in India. When we use the term final it is to emphasize that the form in which we use the decimal place value system today is the one the ancients used in India However, the time and the independence of this invention have been debated. Some say that Babylonian astronomy, with its zero, was passed on to Hindu astronomers but there is absolutely no proof of this, so most scholars give the Hindus credit

[308] *Pingree, D "Zero and the Symbol for Zero in early Sexagesimal and Decimal Place value Systems " in The Concept of Sunya" collection of essays edited by Bag AK., and SK Sarma.*

for coming up with zero on their own. The reason the date of the Hindu zero is in question is because of how it came to be. Furthermore the place value system used by the Babylonians is a two tiered system which uses both the decimal and the sexagesimal. It is also subject to ambiguities and it would require an algorithm for a machine to recognize the number. The final proof of the pudding lies in the fact that both the Arabs and the Europeans after much hemming and hawing decided to adopt the Indian system and by the same token, the Babylonian system simply died away. In fact it is quite obvious in hindsight that the lack of a simple numeral system and the associated technologies such as a symbolic representation of numbers in algebra resulted in the inordinate delay and the epistemological discontinuity, which was only partly rectified in 1560, when the Jesuits came to India on a sleuthing mission. It is best to read the whole story as narrated by CK Raju in his CFM , who did a massive amount of forensic investigation to uncover the trail, which the Vatican had tried so hard to erase ever since they came across the works of pagan civilizations in the Alexandria library.

Most existing ancient Indian mathematical texts are copies that are at most a few hundred years old. And these copies are copies of copies passed through the ages. This is because of the high humidity and the climate which conspire to make chemical degradation of media to accelerate. But the transcriptions are error free…can you imagine copying a math book without making any errors? Were the Hindus very good proofreaders? They had a trick. Math problems were written in verse and could be easily memorized, chanted, or Sung. Each word in the verse corresponded to a number. The sutra technology when set to meter had a check sum to detect errors.

One example of cryptography is as below,
VIYA DAMBAR ĀKĀŚA ŚŪNYA YAMA RAMA VEDA is to be interpreted as follows sky (0) atmosphere (0) space (0) void (0) primordial couple (2) Rama (3) Veda (4)
0 0 0 2 3 4
Indian place notation moved from left to right with ones place coming first. So the phrase above translates to a Mahāyuga 4,320,000.
Using a vocabulary of symbolic words to note zero is known from the 458 CE cosmology text LOKAVIBHAGA. But as a more traditional numeral—a dot or an open circle was used much prior to the date of 628 CE, commonly accepted by Western Indologists, both in the Vedas and by Pingala when discussing the relationship of the Chandas to Pascal's Triangle: Which it probably was, considering that 30 years previously, an inscription of a date using a zero symbol in the Hindu manner was made in Cambodia.

śūnya = void
kha = sky
ākāśa = space
bindu = dot

A striking note about the Hindu zero is that, unlike the Babylonian and Mayan zero, the Hindu zero symbol came to be understood as meaning "nothing." This is probably because of the use of number words that preceded the symbolic zero.

"There is wide ranging debate as to when the decimal place value system was developed, but there is significant evidence that an early system was in use by the inhabitants of the Indus valley by 3000 BC. Excavations at both Harappa and Mohenjo Daro have supported this theory. At this time however a 'complete' place value system had not yet been developed and along with symbols for the numbers one through nine, there were also symbols for 10, 20, and 100 and so on.

The formation of the numeral forms as we know them now has taken several thousand years, and for quite some time in India there were several different forms. These included Kharosthi and Brahmi numerals, the latter were refined into the Gwalior numerals, which are notably similar to those in use today. Study of the Brahmi numerals has also lent weight to claims that decimal numeration was in use by the Indus civilization as correlations have been noted between the Indus and Brahmi scripts.

It is uncertain how much longer it took for zero to be invented but there is little doubt that such a symbol was in existence by 500 BC, if not in widespread use. Evidence can be found in the work of the famous Indian grammarian *Pāṇini* (5th or 6th century BCE; *ed. note - we believe Pāṇini must predate any text written in Classical Sanskrit and at a minimum must have lived prior to 1700 BCE*) and later the work of Pingala a scholar who wrote a work, Chandas-Sūtra (c. 200 BCE). The first documented evidence of the use of zero for mathematical purposes is not until around 2nd century CE (in the Bakṣāli manuscript). The first recorded 'non-mathematical' use of zero dates even later, around 680 AD, the number 605 was found on a Khmer inscription in Cambodia. Despite this it seems certain that a symbol was in use prior to that time. B Datta and A Singh discuss the likelihood that the decimal place value system, including zero had been 'perfected' by 100 BC or earlier. Although there is no concrete evidence to support their claims, they are established on the very solid basis that new number systems take 800 to 1000 years to become 'commonly' used, which the Indian system had done by the 9th century AD.

FIGURE 2 THIS IS A FRAGMENT OF ASOKADITYA'S (AKA SAMUDRAGUPTA) 6TH PILLAR EDICT. ONE CANNOT ASSUME THAT THIS WAS THE SAME ASOKA AS ASOKA MAURYA. IN FACT THE NAME MAURYA DOES NOT APPEAR IN ANY OF THE PILLAR EDICTS.



Part of the reason that unquestioned precedence is not accorded the Vedics is the confusion with the dating of Baudhāyana , Āryabhaţa and Pāṇini , who in my opinion are the leading contenders for the privilege of having invented the zero. It is only recently that it has been universally accepted that the Vedics were the first to use the place value system extensively.

My investigations to date lead me to conclude that the honor of practicing the use of zero and the place value system belongs to one of a select group of individuals among whom are **Āpastamba, Baudhāyana, and/or Pāṇini** . Of course Āryabhaţa was and is a perennial favorite for being the main suspect, provided we admit the possibility of another Āryabhaţa before the Common Era, contemporaneous with the Sulva Sūtra and the Vedāńga Jyotiṣa era. However, we are closing in on the target and should have the answer soon in short order. We will examine the evidence related to each and reach a conclusion. See also the reasons adduced by Ifrah[309].

In the Proposed skeleton of Indian Chronology Baudhāyana is dated at 2000 BCE, which would make him contemporaneous or earlier than the Babylonians.

THE ORIGINS OF TRIGONOMETRY

The history of the trigonometric table is a murky one. This is generally the case when the origin of a subject is not clearly Eurocentric in origin, since the interest of the occidental is, for understandable reasons considerably modulated when he discovers that the origin of a particular field of endeavor is not Greek. There is usually a desperate attempt to retrieve a measure of priority by using the artifice of 'speculative reconstruction'. 'Speculative reconstruction' is the retrospective manufacturing of evidence by those who consider themselves the inheritors and guardians of Greek heritage, to assert that the Greeks did it first. In the case of the Trigonometric table, the occidental usually claims that Hipparchus developed the sine table. The evidence for such a claim is very slim indeed and is based on the

[309] *Ifrah, Georges, The Universal History of Numbers,The Modern Number System, Chapters 24 to 27, John Wiley and Sons, 1998*

statement that Ptolemy refers to the work of Hipparchus. But Ptolemy makes no such reference in the Almagest. In fact the only reference that can remotely be considered Trigonometric in character is his use of Chords. But the absence of clearly defined trigonometric functions and his use of the Pythagoras Theorem, would force us to classify him as being unfamiliar with trigonometric functions in general. If he had known the Tangent function, there would have been no need for the use of Pythagoras theorem. Part of the problem lies in the definition of what constitutes Trigonometry. In this context we will not consider the discovery of PI as being a discovery of Trigonometry. For the purposes of this paper we will define Trigonometry as the science of numerical computation that allows us to convert angular measures into distance measures and vice versa. Using the angular measure as a synonym for linear measures, an insight that is clearly evident in the work and pronouncements of Āryabhaţa and the choice of 3438 minutes (57.2957 degrees or 1 radian) as the radius is not coincidental. However the development of a recursive relationship for $\boldsymbol{\pi}$ or a series expansion of a Trigonometric function that is rapidly convergent with an estimate of the error after n terms would definitely qualify as being a discovery in Trigonometry. Suffice it to say that the result of my investigation into this question has yielded some surprising conclusions.

There is a valiant attempt made to reconstruct the problem of the unequal time periods between the equinoxes and solstices and ascribe the knowledge of the trigonometric functions on the part of Hipparchus by David Bressoud, but again the use of speculative reconstruction to claim priority in a particular discovery, borders on being unethical, because the hope is that the collective memory forgets that it is speculative in the first place and replaces the assumption that this is a plausible approach that might have been used by Hipparchus with the certitude that he in fact was the author of the sine table . Furthermore I do not think it is proper to call such usage as Ptolemy does as an example of Trigonometry. In fact the purpose of devising functions in trigonometry is to avoid the kind of lengthy rationalizations that Ptolemy indulges in. To cite Ptolemy, therefore, as an example of the use of Trigonometry flies in the face of reason. In any event there is great reluctance in the Occident to admit that there is substantial evidence that the origin of trigonometry lies in the Indian subcontinent. In this section we will narrate the origins of the trigonometric function. An adequate history of Trigonometry until the time of Euler needs the attention of a book that is dedicated solely to this topic.

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \cdots$$
$$= \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n+1}}{(2n+1)!},$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \cdots$$
$$= \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n}}{(2n)!}.$$

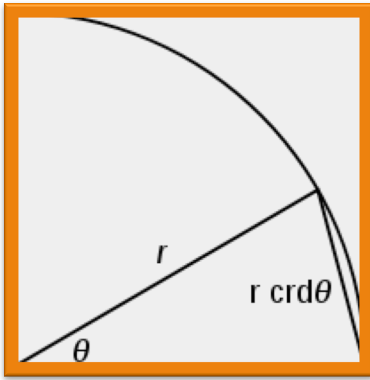
FIGURE 3 DEFINITION OF CHORD

TRIGONOMETRY

Trigonometry[310] is the science of numerical computation that allows us to convert angular measures into distance measures and vice versa. We might be forgiven if this is close to the sense in which the ancient Indics used it. Right from the outset, the Indians concentrated on half the chord and the Versine and the Cosine not as ratios but a length associate with a circle of a definite radius and of course the angle subtended by the radius and its associated side that cut the chord in half.. Thus the ancient Indian sine was written as (see figure 1),

Jya (arc AD) = R sin θ = $\frac{1}{2}$ crd 2 θ or crd θ= 2R sin (θ) = sin θ

[310] *The Mathematics of the Heavens and the Earth: The Early History of Trigonometry By Glen Van Brummelen, Princeton University Press, 2009*



Thus the angular measure of the arc AD is exactly equal to the angle θ. Using the angular measure as a synonym for linear measures, an insight that is clearly evident in the work and pronouncements of Āryabhaţa and the choice of 3438 minutes (57.2957 degrees or 1 radian) as the radius is not coincidental. The arc subtended by a circle of unit radius and unit angular measure (1 radian) measures 1 unit in length. Thus the greatest value of the Sine in ancient India was equal to the Radius R, which is why it is termed the Sinus Totus (total or complete sine). Using only geometry and properties of limits, it can be shown that the derivative of sine is cosine and the derivative of cosine is the negative of sine (as was done by Bhāskara II). (Here, and generally in calculus, all angles are measured in radians; see also the significance of radians below.) One can then use the theory of Madhava-Taylor series to show that the following identities hold for all real numbers *x*:

$\sin^2\theta + \cos^2\theta = 1$, $\sin(\alpha \pm \beta) = \sin\alpha \cdot \cos\beta \pm \sin\beta \cdot \cos\alpha$, $\cos(\alpha \pm \beta) = \cos\alpha \cos\beta \mp \sin\alpha \sin\beta$

It has been alleged, that Chords were used extensively in the early development of trigonometry At least so goes the conventional wisdom in the occident, that the first known trigonometric table, compiled by Hipparchus, tabulated the value of the Chord function for every 7.5 degrees. But there is no evidence that Hipparchus did any such computation. While chords were used by the Greeks, they did not anticipate the versatility of defining an angular measure to represent a distance measurement. The chord function is defined geometrically as in the picture to the left. The chord of an angle is the length of the chord between two points on a unit circle separated by that angle. By taking one of the points to be zero, it can easily be related to the modern sine function:

$$\mathbf{crd}\ \theta = \sqrt{(1 - \cos\theta)^2 + \sin^2\theta} = \sqrt{\{2(1 - \cos\theta)\}} = 2\sin\frac{\theta}{2}$$

The half-angle identity greatly expedites the creation of sine tables in ancient India. Ancient chord tables typically used a large value for the radius of the circle, and reported the chords for this circle. It was then a simple matter of scaling to determine the necessary chord for any circle. AB first used this in a circle of radius 3438' (=3438/60=57.3^{o} or 1 radian). This value is extremely close to 180 / π (=57.29577951...). One advantage of this choice of radius was that he could very accurately approximate the chord of a small angle as the angle itself. In modern terms, it allowed a simple linear approximation:

$$\frac{3438}{60}\,\mathbf{crd}\ \theta = 2\,\frac{3438}{60}\,\mathrm{Sin}\,\frac{\theta}{2} \approx 2\,\frac{3438}{60}\,\frac{\theta}{2}\,\frac{\pi}{180} = \left(\frac{3438}{60}\,\frac{\pi}{180}\right)\theta \approx \theta$$

Where θ is in degrees

In the frenzy for claiming priority, occasioned by the angst that the Greeks would be displaced as the prime and exclusive purveyors of science in the ancient era, B J Toomer not only claims that Hipparchus used a radius of 3438 but he manufactures a hypothetical table using such a radius purportedly satisfying himself that establishing a hypothesis is equivalent to proving the existence of such a document. These are the gentleman who would also remark on the absence of proof in Ancient Indian Mathematics. Again what constitutes proof of existence in the Greek context is apparently not valid in the Indian context. In reality, there is no proof of Hipparchus having done any such thing. This is what is

termed speculative reconstruction among professionals, when they do not wish to give credit to another civilization for purely mendacious reasons.

Sin 2 θ = 2 sin θ cos θ, if θ is a small quantity (<0.1) measured in radians
Sin 2 θ ≈2 θ (1 – θ ^{2}/2), for example if θ = .0654, sin .1308= .1308 (1-.0042716/2) =.13052. The exact value is .13053.

THE VALUE OF PI

The constancy of the ratio of the circumference of any circle to its diameter was known in the ancient world, so that when the circumference is known, the diameter and the radius can be obtained using this ratio which was later termed PI or π.
Thus R = C/ 2 π
π is probably the most ubiquitous among the numerous mathematical constants and it is never a dull exercise to determine who gave what value to π and when, especially in the Ancient era[311]. We are looking, especially for the first occurrence of a recurrence relationship or an infinite series where the value of π can be calculated to any desired accuracy by computing more terms of the series. It is clear that AB knew that any value of π expressed in decimal notation would only be an approximation no matter how many places of decimals one uses. The word आसन्न (approximate) is used in this context; because of their facility with large numbers and infinite series, the Ancient Indic was able to do simple arithmetic as well as algebra and determine whether a particular series would converge and could estimate the resulting error. The Occidental is simply unable to visualize this and says rather glibly, that the Indic never understood the significance of the various discoveries that he made. How can he be so certain, even after all this evidence?

चतुरधिकं शतमष्टगुण द्वाषष्टिस्तथासहस्राणाम् ।
अयूत द्वय विष्कंभस्यासन्नो वृत्त परिणाहः ।।
chaturadhikam Ṡatamaṡţaguṇam dvāṡaṡţistathā sahasrāṇām I
Ayutadvayavi Ṡkambhasyāsanno vrîttapariṇaha II

The circumference of a circle of diameter 20,000 is 62,832.
For C=360^{o} or 21600 minutes, using these values we get;
R =75,000/1309 or 57 + 387/1309 = 57.2956,4553 approximately (correct up to 4 decimal places)

ĀRYABHAŢA'S TABLE OF SINE DIFFERENCES

MAIN FEATURES OF THE TABLE OF SINE DIFFERENCES

The actual Sine difference table appears in the Siddhānta texts such as the Sūrya Siddhānta) and the Paitamaha Siddhānta and *Āryabhaţīya* . The table can be generated using primarily geometric means or it can be done using a highly ingenious technique using second differences (the discrete eqiuivalent of a second derivative). We willl not get into the geometric approach, because conceptually we will not learn anything new by doing so. It is also a more cumbersome procedure.

TABLE 1 THE VALUE OF PI THROUGH THE AGES

[311] *See for instance Kak, SC, 1997b in appendix H*

Name	Era	Value	Notes, Recursive formula used	Error
Yājnavalkya (SB)	3000 BCE	339/108 ≈ 3.139		.08%
Baudhāyana Sulva Sūtras	2500 BCE	3.08	solution to the 'squaring the circle problem	1.9%
Babylonians	2000 BCE	3.125 = 3 + 1/8		.665%
Egyptians	2000 BCE	3.16045		.6%
China	1200 BCE	3		
Jaina astronomers	500 BCE	Sqrt (10)= 3.16227		1%
Bible (1 Kings 7:23)	550? BCE	3		5%
Sūrya Siddhānta	380 BCE	3.1416		
Archimedes	250? BCE	3.1418 (ave.)		
Hon Han Shu	130 CE	3.1622 = sq rt (10)?		
Ptolemy	150	3 3.14166		
Chung Hing	250?	1 3.16227 = sqrt(10)		
Wang Fau	250?	1 3.15555 = 142/45		
Liu Hui	263	5 3.14159	Yes	
Tsu Ch'ung Chi	480?	7 3.1415926		
Āryabhaţa	499	4 3.14156	Yes	
Al-Khwarizmi	800	4 3.1416		
Govindaswami	(c. 800-850)	8 decimal places		
Fibonacci	1220	3 3.141818		
Mādhava of Saņgamagrāma	1395	infinite series for PI(later known as Gregory Series)	Yes	
Jyeşţhadeva	1550	3.14159265359	Yes	
Otho	1573	3.1415929		
Viete	1593	3.1415926536 (ave.)		

TABLE 2 ĀRYABHAŢA'S SINE DIFFERENCE TABLE					
Actual value R sin nθ, Minutes	Actual modern value **R sin nθ** radians	Actual Sine diff $\mathbf{D_n}$	Āryabhaţa 's Sine diff, rounded to the minute	Govindaswami fractional parts	Āryabhaţa's sine diff improved by Govindaswami
224; 50, 19, 56	.0654	224; 50	225	-9,37	224; 50, 23
448; 42, 53, 48	.13053	223; 52	224	-7,30	223; 52, 30
670; 40, 10,24	.19509	221; 57	222	-2,42	221; 57, 18
889; 45, 8, 6	.25882	219; 4	219	+ 4,57	219; 4,57
1105; 1, 29, 37	.32144	215; 16	215	+16,22	215; 16, 22
1315; 33, 56, 21	.38268	210; 32	210	+32,26	210; 32, 26
1520; 28, 22, 38	.44229	204; 54	205	-5,34,	204; 54, 26
1718; 52, 9,42	.5	198; 23	199	-36,12	198; 23,48
1909; 54, 19, 5	.55557	191; 2	191	+ 2,09	191;2,09
2092; 45, 45, 51	.60876	182; 51	183	-8.33	182;51, 27
2266; 39, 31, 6	.65934	173; 53	174	-7,02	173; 52, 58
2430; 50, 54, 6	.70711	164; 11	164	+12,10	164; 12, 10
2584; 37, 43, 44	.75184	153; 46	154	-13,11	153; 46, 49
2727; 20, 29, 23	.79335	142; 42	143	-17,14	142; 42, 46
2858; 22, 31, 0	.83147	131; 2	131	+ 2,02	131; 2,02
2977; 10, 8, 37	.86603	118; 47	119	-12,22	118; 47, 38
3083; 12, 50, 56	.89687	106; 2	106	+ 2.42	106; 2,42
3176; 3,23, 11	.92388	92; 50	93	-9,28	92; 50, 32
3255;17,54,8	.94693	79; 14	79	+14,31	79; 14,31
3320; 36, 2, 12	.96593	65; 18	65	+18.08	65; 18,08
3371; 41, 0,43	.98079	51; 4	51	+ 4,59	51; 4, 59
3408; 19, 42, 12	.99144	36; 38	37	-21,19	36; 38,41
3430; 22, 41, 43	.99785	22; 2	22	+ 3,00	22; 3,00
3437; 44, 19, 23	1.00000	7; 21	7	+21,37	7;21,37

Āryabhaţa's approach to the Sine table is a highly original one. The first major intellectual leap that he made was his choice of units. The notion that a linear measure could be expressed as an angle is an innovation that permits a lot of flexibility and easy deductions that are not immediately apparent in the use of half chords that the Alexandrian astronomers used. Secondly, and more importantly, by defining functions such as Jya, Kotijya, and Utkramjya, he laid the groundwork for the subsequent development of the infinite series, the calculus, and the beginnings of analysis.

R = 21,600/2 π = 10,800/ π = 3437.7 in minutes
1 radian = 57.2957° = 180/π degrees . In order to read the numbers in radians , divide by 60, and in order to get the modern value of Sine divide the value in the table by 10,800/ π. So also is his use of a recursive formula. There is an elegance and beauty in this algorithm, which uses second order differences that simply takes ones breath away. But before we go on, we note that the
Sine function is the solution of one of the simplest second order differential equations. But differential equations were not invented then.
Y'' + Y = 0 where Y '' stands for the second derivative of **Y**
R is the measure in angular units , of the radius of a circle with circumference equal to 21,600 minutes or 360° and is also the measure of the arc of a circle subtended by 1 radian or 57.2957°. While the Occidental did not coin a name for the radian till 1733 CE, the Indians were always working with angular measures

However we feel that the ancients did the next most suitable computation using difference equations. They chose a Radius (360° = 21,600 ').
The recursive algorithm for generating the Sine difference table in Sūrya Siddhānta and *Āryabhaţīya* . which we shall term **eqn. SD 1** (the second one)

$$R_N = R_{N-1} + \Delta_N$$
$$\Delta_N = \Delta_{N-1} - (R_{N-1} / R_1)(\Delta_1 - \Delta_2)$$

RATIONALIZATION OF RECURSIVE RELATION

The rationale for the recursive relation is as follows

$$\delta_n - \delta_{n+1} = (R_n - R_{n-1}) - (R_{n+1} - R_n)$$
$$= r \sin n\theta - r \sin (n-1)\theta - \{r \sin (n+1)\theta - r \sin n\theta\}$$

Expanding Sin (n+1) θ we get

$$= 2r \sin n\theta \{(1 - \cos\theta)\} = 2 R_n (1-\cos\theta)$$

Or

$$(\delta_n - \delta_{n+1})/R_n = 2(1 - \cos\theta) = 2\text{versin}\,\theta = 2 \text{ sara } \theta = 2 \text{ utkramjya } \theta$$

……We will call this ………………………………………………………………………………………. **SD 2**
Notice that this is an exact relationship and there is as yet no approximation made
Instantiating for n=1, we get
$\delta_1 - \delta_2 = 2R_1 \{1-\cos\theta\}$. This is not an approximation. Making the appropriate substitution

$$\delta_n - \delta_{n+1} = (R_n / R_1)(\delta_1 - \delta_2),$$

$$(\delta_n - \delta_{n+1}) / R_n = (\delta_1 - \delta_2) / R_1$$

..................eqn. **SD3** which is equivalent to **SD1**
Instantiating the constant (this where we make the approximation

$(\delta_1 – \delta_2) / R_1 \sim 1/225$

$\delta_n - \delta_{n+1} = R_n/ 225$ or $(\delta_n - \delta_{n+1}) /R_n = 1/225$.

We will call it …..……………………………. **SD5**

Notice that this is not a recursive relation when the second difference is represented as a ratio. But the major approximation here is that the first value of the second difference is 1.

We get the desired result for the second order difference in terms of the original function. This is the dimensionally incorrect version that most commentators have attributed to AB, whereas Nīlakaṇţa, almost a thousand years later gives the dimensionally correct version , which does not make a priori assumption about the degree of accuracy desired in the result and does not make the a priori assumption that $\boldsymbol{\delta_1 – \delta_2 = 1}$

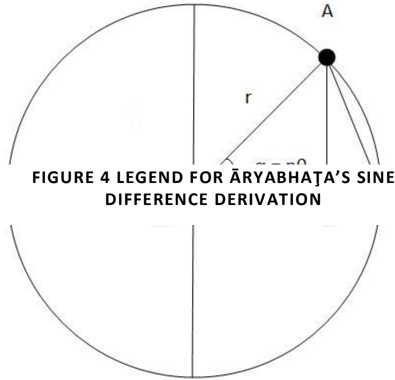


FIGURE 4 LEGEND FOR ĀRYABHAŢA'S SINE DIFFERENCE DERIVATION

Nilakanta's values are R_1 = [224;50;22]= 224.8394444444 , R_2 = [448;42;58]= ,so that $\delta 2$ = [223;52;36]= 223.8766666667 , and $\delta_1 – \delta_2$ = [0;57;46]= 0.9627777778 (See Raju, CFM)

Then there is the alternate derivation, using the approximation that the very first chord R_1 = the arc length Rθ and by definition $\boldsymbol{\delta_1 = R_1}$ **or** $\boldsymbol{\delta_1 /R = RSin\ \theta /R}$. Therefore,

$(\delta_n - \delta_{n+1})/R_n = 2(1- \cos \theta) = 4 \sin^2 (\theta/2) <= \theta^2$

Approximation: Since, $\boldsymbol{4\sin^2 (\theta/2) \sim \theta^2}$ for small values of θ , which is equivalent to assuming that the initial value of the sine.

The difference is the same as the length of the arc (this is 225 in the case of AB's table)

$\delta_1 = R_1 = 225$, $\theta = 225/3438 =0.0654450262$

Instantiating for n=1

$(\delta_1 - \delta 2)/R_1 = \theta^2 = 4.2830514514e-3$, $\delta_1 - \delta_2 = R_1\theta^2$, $\delta_2 = R_1 (1-\theta^2)$

$\delta_2 = R_1 * (1 – \theta^2) = 225 \{ 1 – (225/3438)^2 \}= 224.0363134$

$R_2 = R_1 + \delta_2 =449.0363134$

$\delta_2 - \delta_3 = R_2 \theta^2$ and $(\delta_n - \delta_{n+1}) = R_n \theta^2$ …………………………………………………………………**……….……..SD4**

For n= 2, 3…24

$\boldsymbol{(\delta_n - \delta_{n+1}) / R_n = \theta^2}$**, which is** Nilakanta's 2nd order difference……………………………………….. SD4

Note that the second difference is proportional to the negative of the function which is analogous to the second derivative being proportional to the negative of the function , the solution for such a differential equation is the Sine function or exp (ix)t. I call this the Nīlakaṇţa approximation to distinguish it from the AB approximation.

Legend for, OB = r **kojya** (α) = r Cos α. OC = r, BC= r **utkramjya** (α) = r **Sara** (α) = r vers α = r (1- cos α), AB = r **jya** (α) = r sin α, AC = 2 r jya (α/2) = 2 r Sin α/2, α = angular measure of nth division = nθ, n = 1.2….N, where Āryabhaţa chooses 24

θ = 225 minutes = $3^o 45'$ = 0.0654498469

Sin θ = 0.0654031292,
θ^2 = 4.2836824658e-3. This starts of the recursion on a more accurate note than
1/ R1 = 1/225 = 4.4444444444e-3

We start the recursive operation with R_o and δ_o = 0 and $R_1 = \delta_1$ =arc = 225'.
Thus R_1 is equal to $3^o\ 45'$ (remember we are subtending the quadrant into 24 equal parts.
The sine of 225 which we need to obtain is 0.06544, accurate to 4 significant places. The

Circumference of the circle of unit radius =360^o or 21,600 ' = 2 π = 6.2831853 radians
So one quadrant of a circle = 5400'= π /2 = 1.5707963
So that each segment of the quadrant = 5400/24 = 225 ' or 3^o45'= π/48 = .06544 radians

Why does he choose 24 divisions? A commentator **Sūryadeva Yajwan**[312] gives the explanation
"Now why should there be a rule that the number of jya's be restricted to 24, when the quadrant of a circle can be divided into any number of parts. The quadrant should be divided in such a manner that the first jya and the corresponding arc are equal to a certain significant number of digits. This is the case when the number of parts in the quadrant is 24
Thus the value of the first sine difference is equal to the sin 225 or 225/3438 = .06544 in radians Thus the algorithm starts off with an approximation, which is exact to 4 significant places. Now using Āryabhaţa's recursive relations,
$\delta_2 = R_1 - (R_1/\ R_1)$ = 225 -1 = 224
By definition R2 = $R_1 + \delta_1$ = 449'
Similarly $\delta_3 = \delta_2$- R2 /R_1, = 224 – 449/225 = 222, so that $R_3 = R_2 + \delta_3$ = 671. Further $\delta_4 = \delta_3 - R_3/R_1$ = 222-671/225 = 219 and R_4 = 890' and the calculation can be continued. The standard the Ancient Indic was not limited to expressing the length of a linear segment by a linear measure. He was equally comfortable expressing curvilinear distances as an angular measure. Thus R (the length of the arc as well as the radius) can be equally well expressed as an angular distance of 1 radian as its traditional measure which uses units of linear measure.
1 radian, 57.2957^o or as 3438'
R = 10800/3.1416 = 3437.787, h = 225'= 3^o 45'=180/48= π/48 radians , n = 1,23.3 …24

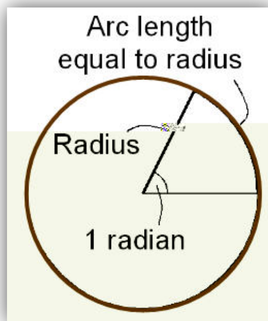
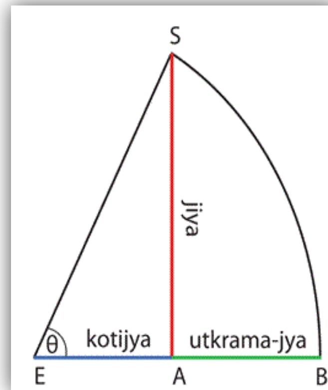


FIGURE 6 NOTION OF A RADIAN



The radian is a unit of plane angle, equal to 180/π (or 360/(2π)) degrees, or 57.2958 degrees, or about 57°17′45″. It is the standard unit of angular measurement in all areas of mathematics beyond the elementary level.
The radian is represented by the symbol "rad" or, more rarely, by the superscript c (for "circular measure"). For example, an angle of 1.2 radians would be written as "1.2 rad" or " 1.2^c " (the second symbol is often mistaken for a degree: " 1.2° "). However, the radian is mathematically considered a "pure number" that needs no unit symbol,

[312] *see Chapter XI on Indic savants*

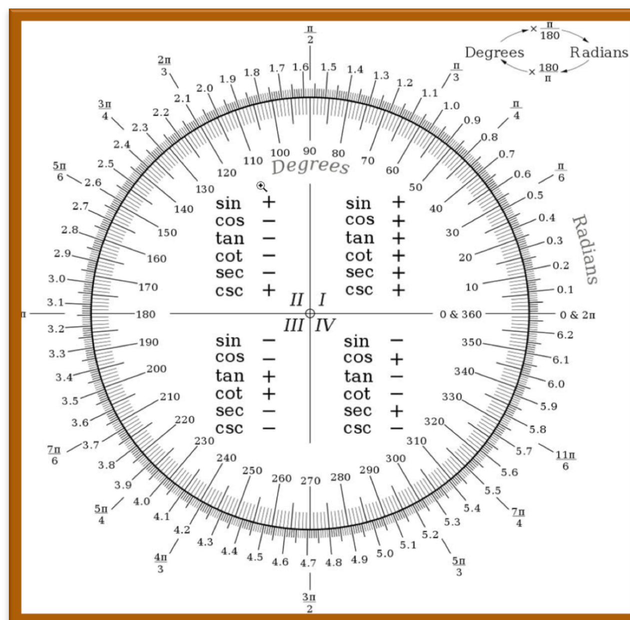
and in mathematical writing the symbol "rad" is almost always omitted. In the absence of any symbol radians are assumed, and when degrees are meant it is customary to use a zero as a superscript.

FIGURE 5 INDIC TRIGONOMETRIC FUNCTIONS

One radian is the angle subtended at the center of a circle by an arc that is equal in length to the radius of the circle. More generally, the magnitude in radians of such a subtended angle is equal to the ratio of the arc length to the radius of the circle; that is, θ = s /r, where θ is the subtended angle in radians, s is arc length, and r is radius. Conversely, the length of the enclosed arc is equal to the radius multiplied by the magnitude of the angle in radians; that is, s = rθ.
It follows that the magnitude in radians of one complete revolution (360 degrees) is the length of the entire circumference divided by the radius, or 2πr /r, or 2π. Thus 2π radians are equal to 360 degrees, meaning that one radian is equal to 180/π degrees."
Quote from Wiki "The concept of radian measure, as opposed to the degree of an angle, should probably be credited to Roger Cotes in 1714. He had the radian in everything but name, and he recognized its naturalness as a unit of angular measure." If that is the criterion for according priority for an invention, then the credit for the radian should go to Āryabhaţa, who had the concept of the radian while developing the algorithm for the table of sine differences. In effect his Trigonometric table was for Rsine, the value of R was 1 radian. The term radian first appeared in print on 5 June 1873, in examination questions set by James Thomson (brother of Lord Kelvin) at Queens College, Belfast. He used the term as early as 1871, while in 1869, Thomas Muir, then of the University of St Andrews, vacillated between rad, radial and radian. In 1874, Muir adopted radian after a consultation with James Thomson.[313,314]

SOME DEFINITIONS IN SPHERICAL GEOMETRY

GREAT CIRCLES
The shortest path between two points on a plane is a straight line. On the surface of a sphere, however, there are no straight lines. The shortest path between two points on the surface of a sphere is given by the arc of the great circle passing through the two points. A great circle is defined to be the intersection with a sphere of a plane containing the center of the sphere.
If the plane does not contain the center of the sphere, its intersection with the sphere is known as a small circle.
TWO SMALL CIRCLES (Figure 8 & 9)



[313] http://jeff560.tripod.com/r.html
[314] *Florian Cajori A history of Mathematics, American Mathematical Society Publishing, Chelsea,, NY*

In more everyday language, if we take an apple, assume it is a sphere, and cut it in half, we slice through a great circle. If we make a mistake, miss the center, and hence cut the apple into two unequal parts, we will have sliced the apple into 2 smaller circles.

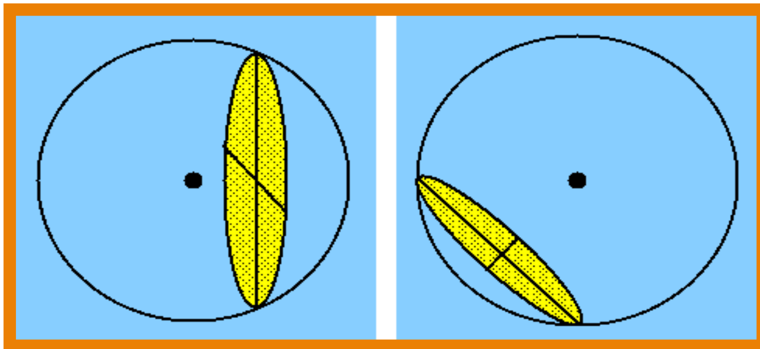


FIGURE 8 AND 9 SMALL CIRCLES ON A SPHERE

Figure 10 shows a spherical triangle ABC, formed by three intersecting great circles, with arcs of length (a,b,c) and vertex angles of (A,B,C). Note that the angle between two sides of a spherical triangle is defined as the angle between the tangents to the two great circle arcs, as shown in figure 12 for vertex angle B.

FIGURE 10 WHAT IS A SPHERICAL TRIANGLE

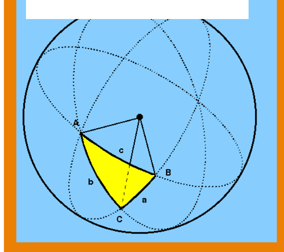
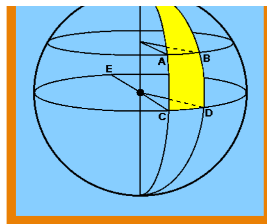
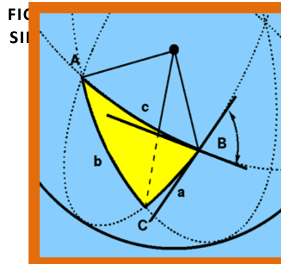
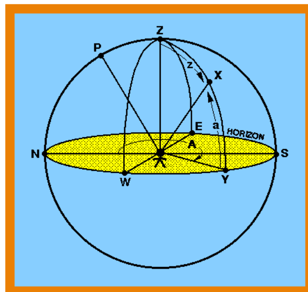


FIGURE 11 PAB IS NOT SPHERICAL TRIANGLE



FI
SI





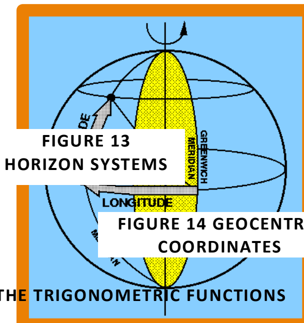


FIGURE 13 HORIZON SYSTEMS

FIGURE 14 GEOCENTRIC COORDINATES

FIGURE 7 QUADRANTAL MAPPING OF THE TRIGONOMETRIC FUNCTIONS

If we wish to connect three points on a plane *using the shortest possible route, we would draw* straight lines and hence create a triangle. For a sphere, the shortest distance between two points is a great

circle. By analogy, if we wish to connect three points on the surface of a sphere using the shortest possible route, we would draw arcs of great circles and hence create a spherical triangle. To avoid ambiguities, a triangle drawn on the surface of a sphere is only a spherical triangle if it has all of the following properties: The three sides are all arcs of great circles. Any two sides are together greater than the third side. Hence, in figure 11 triangle PAB is not a spherical triangle (as the side AB is an arc of a small circle), but triangle PCD is a spherical triangle (as the side CD is an arc of a great circle). You can see that the above definition of a spherical triangle also rules out the "triangle" PCED as a spherical triangle, as the vertex angle P is greater than 180° and the sum of the sides PC and PD is less than CED.

EARTH'S SURFACE (see Figure 15)

The rotation of the Earth on its axis presents us with an obvious means of defining a coordinate system for the surface of the Earth. The two points where the rotation axis meets the surface of the Earth are known as the North Pole and the South Pole and the great circle perpendicular to the rotation axis and lying half-way between the poles is known as the equator. Great circles which pass through the two poles are known as meridians (Figure 14) and small circles which lie parallel to the equator are known as parallels or latitude lines. The latitude of a point is the angular distance north or south of the equator, measured along the meridian passing through the point. A related term is the co-latitude, which is defined as the angular distance between a point and the closest pole as measured along the meridian passing through the point. In other words, co-latitude = 90° - latitude.

Distance on the Earth's surface is usually measured in nautical miles, where one nautical mile is defined as the distance subtending an angle of one minute of arc at the Earth's center. A speed of one nautical mile per hour is known as one knot and is the unit in which the speed of a boat or an aircraft is usually measured.

Humans perceive in Euclidean space i.e. straight lines and planes. But, when distances are not visible (i.e. very large) than the apparent shape that the mind draws is a sphere ; the advantage is that we can project Earth reference points (i.e. North Pole, South Pole, equator) onto the sky. Note: *the sky is not really a sphere!.*

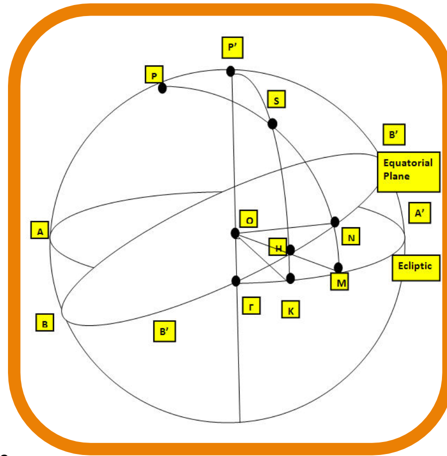
This system allows one to indicate any position in the sky by two reference points, the time from the meridian and the angle from the horizon. Of course, since the Earth rotates, your coordinates will change after a few minutes. The horizontal coordinate system (commonly referred to as the alt-az system) is the simplest coordinate system as it is based on the observer's horizon. The celestial hemisphere viewed by an observer on the Earth is shown in figure 13. The great circle through the zenith Z and the north celestial pole P cuts the horizon NESYW at the north point (N) and the south point (S). The great circle WZE at right angles to the great circle NPZS cuts the horizon at the west point (W) and the east point (E). The arcs ZN, ZW, ZY, etc, are known as verticals.

The two numbers which specify the position of a star, X, in this system are the azimuth, A, and the altitude, a. The altitude of X is the angle measured along the vertical circle through X from the horizon at Y to X. It is measured in degrees. An often-used alternative to altitude is the zenith distance, z, of X, indicated by ZX. Clearly, $z = 90 - a$. Azimuth may be defined in a number of ways. For the purposes of this course, azimuth will be defined as the angle between the vertical through the north point and the vertical through the star at X, measured eastwards from the north point along the horizon from 0 to 360°. This definition applies to observers in both the northern and the southern hemispheres.

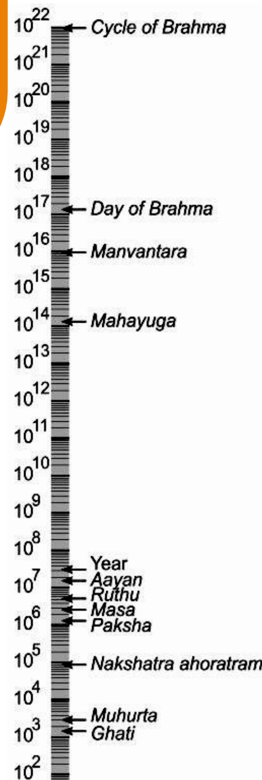
LEGEND FOR FIGURE 15 POLAR LONGITUDE (IN SŪRYA SIDDHĀNTA)

- P = Celestial Pole
- BB' = Celestial Equator
- AA' = Ecliptic

FIGURE 15 POLAR LONGITUDE (IN SŪRYA SIDDHĀNTA)



It is often useful to know how high a star is above the horizon and in what direction it can be found - this is the main advantage of the alt-az system. The main disadvantage of the alt-az system is that it is a local coordinate system - i.e. two observers at different points on the Earth's surface will measure different altitudes and azimuths for the same star at the same time. In addition, an observer will find that the star's alt-az coordinates changes with time as the celestial sphere appears to rotate. Despite these problems, most modern research telescopes use alt-az mounts, as shown in the figure above, owing to their lower cost and greater stability. This means that computer control systems which can transform alt-az coordinates to equatorial coordinates are required.



- O= Center Earth
- P' = Ecliptic Pole
- S = Location of star
- Or any object
- β = SK = Celestial latitude = ∡ΓOK
- SN = Declination = δ = **∡NOS**
- α = ΓN = right ascension
- MP = hour circle
- P'SK = great circle passing through the ecliptic pole
- ε = obliquity
- λ = SK = celestial longitude
- λ′ = ΓM = Polar longitude =Dhruvaka = ∡ ΓOM
- β′ = SM = Polar latitude =Vikshepa = **∡SO**M

Polar Longitude and Polar Latitude do not constitute a set of orthogonal coordinates

Note that the great circle (meridian) PSM passing through S and P the celestial pole, will not make a right angle with the ecliptic plane.

- Δλ = KM = difference between Celestial Longitude and Polar Longitude = λ′ - λ
- Āryabhaţa 's approximation
- Δλ = KM = (Rβ * R vers λ + R sin ε)/ R^2
- λ′ = λ + Δλ

- λ= ΓK = celestial longitude in radians
- ε = obliquity

To find the declination δ from polar longitude, for a planet or a star on the ecliptic, Āryabhaţa gives the following approximation

$\sin \delta = \sin \lambda' \sin \varepsilon$

THE INDIC PENCHANT FOR LARGE NUMBERS

The use of Powers of ten to denote large numbers dates back to high antiquity. In fact as far as we are aware, there is absolutely no trace of any extensive use of any other base of numeration in the entire Sanskrit literature. It is also characteristic of India that there is evidence at a very early date in high antiquity, of a long series of number names for very high numbers. In contrast the Greeks had no terminology for numbers above the myriad (10^4) and the Romans above the mille (10^3). There is a story associated with the use of large numbers and Gautama Buddha, the Bodhisattva himself. Our dating of the Buddha is 1887 – 1807 BCE for reasons that are elaborated in Volume 1 of this series, but even if we take the much later date of 550 BCE touted by Occidental Indologists, it is still a remarkable story that emphasizes the widespread use of large numbers during the time of the Buddha. The story is recounted in the Lalitavistara Sutra[315]. It is a text about the life of the Prince Gautama Siddhartha, where he

[315] Lalitavistara by Rajender Lal Mitra,. Calcutta. Compiled , terminus ante quem of 308 BC

becomes adept in all the sciences, while still a boy. It tells of the evaluation of the number of grains of sand in a mountain. The incident takes place in a dialogue between Arjuna, the mathematician, and the Bodhisattva when he was young.
In the Yajur Veda Saṃhitā Vājanaseyī (YVVS)[316], the following list of numeral denominations is given;

The mathematician asks the Bodhisattva 'O young man, do you know the counting which goes beyond the koti on the centesimal scale. The Buddha replies in the affirmative.
Arjuna how does the counting proceed beyond koti on the centesimal scale?
The Buddha then recounts all the names of powers of ten until he reaches 10^{53} (Tallakshana).

SUMMARY OF MACRO AND MICRO UNITS OF TIME

A Tithi (also spelled *thithi*) or lunar day is defined as the time it takes for the longitudinal angle between the moon and the sun to increase by 12°. Tithis begin at varying times of day and vary in duration from approximately 19 to approximately 26 hours (see also Chapter I and VI)
A *paksa* (also Pakṣa) or lunar fortnight consists of 15 **Tithis**
a *māsa* or lunar month (approximately 29.5 days) is divided into 2 **Pakṣas**: the one between new moon and full moon (waxing) is called *gaura* (bright) or *Śukla Pakṣa*; the one between full moon and new moon (waning) *Kṛṣṇa* (dark) *Pakṣa.*

LUNAR METRICS

A kshanas is 3 nimeṣas.
A kashthas is 5 kshanas, or about 8 seconds.
A laghu is 15 kashthas, or about 2 minutes. [2]
15 laghus make one nadika, which is also called a danda. This equals the time before water overflows in a six-pala-weight [fourteen ounce] pot of copper, in which a hole is bored with a gold probe weighing four masha and measuring four fingers long. The pot is then placed on water for calculation.
2 dandas make one muhurta.
6 or 7 muhurtas make one yamah, or 1/4th of a day or night.
4 praharas or 4 yamas are in each day or each night.
A ritu (or *season*) is 2 māsa

TABLE 3 NAMES FOR POWERS OF TEN						
Eka 1	dasa 10	Sata 100	Sahasra 10^3	Ayuta 10^4	Niyuta, laksha10^5	Prayuta 10^6
Arbudakoti 10^7	Nyarbuda 10^8	Samudra,satakoti 10^9	Madhya 10^{10}	Anta 10^{11}	Parārdha 10^{12}	Viskhamba 10^{15}
Mahākshoni 10^{17}	Kumud 10^{21}	Kshoba 10^{22}	Ninahuta 10^{35}	Niravadya 10^{41}	Sarvajna 10^{49}	Vibhutangama 10^{51}
Tallakshana 10^{53}	Abbuda 10^{56}	Sogandhika 10^{95}	Uppala 10^{98}	Kumuda 10^{105}	Pundarika, 10^{112}	Paduma 10^{119}

An *ayanam* is 3 rituhs
A year is 2 āyanas
Small units of time used in the vedas (one can see that there is as yet no standardization)
1 trasarenu = 3 anu.
A truti is the time needed to integrate 3 trasarenus, or 1/1687.5th of a second.
A vedha is 100 trutis.
Lava is 3 vedhas.
A nimeṣa is 3 lavas, or a blink. = 2700 trasarenu

TABLE 4 NINE MEASURES OF TIME RECKONING DEFINED IN SŪRYA-SIDDHĀNTA	
METRIC OF MEASUREMENT	UNIT USED
SIDEREAL (NAKṢATRIC)	SIDEREAL DAY =ONE STAR RISE TO THE NEXT
LUNAR (CHANDRAMĀSA)	LUNAR MONTH = ONE NEW MONTH TO THE NEXT
Solar (Sauramāsa)	Solar Year = Period of one solar revolution
Civil (Sāvana Dina)	Civil Day = One sunrise to the next
Brahma	Brahma Day = Period of 2 Kalpas
Jovian	Jovian Year = period of Jupiter's motion through a sign (30^o)
Paternal (manes)	Day of manes = One lunar month
Divine Day (Divya)	Day of the Devas = One Solar year
Malefic(Āsuric)	Day of Demons = One solar year

LUNAR METRICS

A kshanas is 3 nimeṣas.
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6 or 7 muhurtas make one yamah, or 1/4th of a day or night.
4 praharas or 4 yamas are in each day or each night.
Various Time Frames Described
Pitr
Deva:-
Brahma
Krati = 34,000th of a second
Truti = 300th of a second
Truti = 1 Luv
Luv= 1 Kshana
Sidereal metrics

one sidereal day	$23^h\ 56^m\ 03.4446^s$
sixty nadis	$23^h\ 56^m\ 03.4446^s$
one nadi (ghatika)	$23^m\ 56.06^s$
vinadi	23.93^s (vighati)
one prana	3.99^s (time for a breathing cycle

A Paramānus () is the normal interval of blinking in humans, or approximately 4 seconds
A vighaṭi (विघटि) is 6 paramānus, or approximately 24 seconds
A ghatiya (घटि) is 60 vighatis, or approximately 24 minutes,1/2 Muhurta = Nadi
A muhurta is equal to 2 ghadiyas, or approximately 48 minutes = 2 Nadis
A Nakṣatra ahoratras (नक्षत्र अहोरत्रम्) or sidereal day or nycthemeron is *exactly* equal to 30 muhurtas (Note: A day is considered to begin and end at sunrise, not midnight
Time measurement
An alternate system described in the Vishnu Purāṇa Time measurement section of the Vishnu Purāṇa Book I Chapter III is as follows:

10 blinks of the eye = 1 Káshṫhá
35 Káshṫhás = 1 Kalá == 144 seconds
20 Kalás = 1 Muhúrta =48 minutes (compare with Pala and Vipala)
30 Muhúrtas = 1 sidereal day (24 hours) = 1 Nakṣatra ahorātra
30 days = 1 month
6 months = 1 Ayana
2 Ayanas = 1 year or one day (day + night) of the gods

30 Kshana = 1 Vipal
60 Vipal = 1 Pal = 60 Paraghatis = 1 Vighati ~24 seconds
60 Pal = 1 Ghati = 60 Vighatis = 1Ghati ~ 24minutes

60 Ghatis = 1 Day = 30 Muhurta
1 Muhurta = 48 minutes = 2 Ghatis
2.5 Ghati = 1 Hora (1 hour)
60 Sukshma Ghatis = 1 Paraghhati = 0.4seconds
24 Hoar = 1 Divas (1 day)
7 Divas = 1 Saptah (1 week)
4 Saptah = 1 Māsa (1 month)
2 Māsa = 1 Ritu (1 season)
6 Ritu = 1 Varṣa (1 year)
100 Varṣa = 1 Shatabda (1 Century) = 100 years
10 Shatabda = 1Sahasrabda = 1000 years
432 Sahasrabda = 1 Yuga (1 Kaliyuga) =432,000 years
2 Yuga = 1 Dwāparyuga = 864,000 years
3 Yuga= 1 Tretayuga = 1,296,000 years
4 Yuga = 1 Kritayuga = 1,728,000 years
10 Yuga = 1 Mahāyuga = 10 kaliyugas = 4,320,000 years
1000 Mahāyuga = 1 Kalpa = 4,320,000,000 years
1 Kalpa = 4.32 billion years
1Brahma Day = 1 Kalpa
1 Brahma Day and Night = 8,640,000,000 years

METRIC OF ANGULAR MEASUREMENT

1 Amsa = 1 degree
1 kalā= 1 arc minute = 1/60 of 1^{o}
1 Vikala = 1/60 of a arc minute = 1 arc second

THE OCCIDENTALIST CRITIQUE OF THE INDIC VIEW OF THEIR ACHIEVEMENTS IN ANTIQUIITY

I posted the review of the book by Sarkar, Benoy Kumar, written during the early years of the 20^{th} century here in order to show how a supposedly liberal Occidental trashed the book in merciless terms. His first objection is that the author is an extreme nationalist. Note that when he uses the term extreme he does not mean that the person is a violent jihadi, but one who is strongly patriotic. If that was the sole reason to disqualify a person for writing the history of a people, then it should automatically disqualify Charles de Gaulle and Winston Churchill from claims to be serious historians. It is such non-sequiturs that completely shatter the illusion that most scholars in the west are fundamentally unbiased when it comes to the achievements of nations that are different from the European in obvious and superficial characteristics. Even the slightest mention of a priority invites a stern rebuke or ridicule, all the while making the disclaimer that 'My enthusiasm for India is no less than the author'. He is especially scornful of the author's statement or thesis that '*Every attempt on the part of modern scholars to trace the Hellenic or Hellenistic sources of Hindu learning has been practically a failure. India's indebtedness to foreign peoples for the main body of her culture is virtually nil.'*

This is not very far from our viewpoint. The vehemence and the certainty with which he refutes these statements evokes from us the Shakespearean response 'Methinks he doth protest too much.

"Hindu Achievements in exact Science" by B LAUFER A review of the book by Sarkar, Benoy Kumar study in the history of scientific development. Longmans, Green and Co.: New York, The review appeared in 1918. P.82 American Anthropologist

The ethnologist is always gratified at a book in which the achievements of a people outside the pale of our narrow culture-sphere are vividly and forcibly expounded. Professor Sarkar desires to furnish for popular consumption "some of the chronological links and logical affinities between the scientific investigations of the Hindu and those of the Greeks, Chinese, and Arabs," without going into technical details or relating the migration of ideas. He briefly sets forth, without giving new facts, what the Aryan stock of ancient India has accomplished in mathematics, astronomy, physics, Chemistry, metallurgy, medicine, and natural history. Owing to its simple and succinct presentation, his book will doubtless find many readers, and I hope that these will not be confined to students interested in the history of science, but that also many ethnologists will imbibe its lessons, for all science has emerged from the domain of folklore. In making this recommendation, however, it is the reviewer's duty to call attention also to the weak points of the book.

Mr. Sarkar does not entirely escape from the exaggerations of the specialist, but, what is far worse writes from the standpoint of the extreme nationalist. The nationalist movement among the highly educated and intelligent Bengali is in itself an interesting phenomenon, yet, whatever the merits and drawbacks of nationalism may be (many of us who have the progress of mankind at heart are absolutely opposed to it), it must never be wedded to science. The history of science can be written only from the universal, broad-minded, and sympathetic viewpoint of humanity, and it makes no difference to the true humanist whether an idea or discovery is due to India or China, to the Greeks or the Arabs, to the Negroes or the Maya. Apodictic and dogmatic assertions, such as "the Hindu were the first to discover gold," and "the Hindu taught the world the art of extracting iron from the ores" (p. 68) cannot be subscribed to by any one; nor is it true that the Hindu discovered zinc during the fourteenth century; at a much earlier date zinc was extracted from the ore in Sassanians Persia and from that quarter became known in China. Charaka and Sushruta were assuredly great physicians, but it is hardly necessary to praise them at the expense of Galen or to belittle Theophrastus or Pliny. Mr. Sarkar's mind is too full of modern scientific facts and terminology and too prone to interpret and to project these without moderation into the thoughts of the Indians.
In natural history considerable power of observation was exhibited, as well as remarkable precision in description, and suggestiveness in expression. Their nature study was oriented to the practical needs of socio-economic life. It was minute and comprehensive, and so far as it went, avoided the fallacies of mal-observation and non-observation. Whatever be the value of the results achieved, the investigation was carried on in a genuine scientific spirit (p. 67). These exuberant remarks are not warranted by five-toed animals (cf. M. Chakravarty, Animals in the Inscriptions of Piyadasi! ; until the dawn of our science of zoology it was only the Chinese and the great Al-Biruni who knew correctly that the animal was possessed of three hoofs on each foot. In The Diamond (p. 65) I have given a good instance of how the modern Indian school proceeds to claim European discoveries as their own simply by reading into their texts what these do not say, and thus to proclaim the phosphorescence of the diamond as an Indian asset centuries before Boyle. "India was the greatest industrial power of antiquity. It was the manufactures of the Hindu, which, backed up by their commercial enterprise, served as standing advertisements of India in Egypt, Babylonia, Judea, Persia, etc. To the Romans of the imperial epoch and the Europeans of the middle Ages, also, the Hindu was noted chiefly as a nation of industrial experts.
The mere intimation to conceive the Indians as industrialists and advertisers makes me shiver.
The compass as an early invention of India (p. 38) Is adopted from Mookerji, but, as shown by me (this journal, 1917, p. 77), this interpretation rests on a fallacy. There is, moreover, no Sanskrit work which mentions the compass. The invention of gun-powder in India is nothing but a learned fable based on the antedating of recent texts, misunderstandings and misinterpretation of terms, seasoned with a strong dose of imagination and uncritical methods. According to the school to which Mr. Sarkar belongs, chemistry that is, alchemy, is of perfectly indigenous growth in India: the Hindu chemical

investigators of the fifth and sixth centuries A.D. Even anticipated by one millennium the work of Paracelsus and Libavius, and the physico-chemical theories as to combustion, heat, chemical era, and was thence transmitted to India and China. Mr. Sarkar undervalues the expansion and influence of Hellenism, for he states.

Every attempt on the part of modern scholars to trace the Hellenic or Hellenistic sources of Hindu learning has been practically a failure (p. 5); and his patriotism culminates in the dogma, India's indebtedness to foreign peoples for the main body of her culture is virtually nil.

This is plainly unsound super-Indianism. My enthusiasm for India is no less than that of our author, but I have been inconsiderate enough to demonstrate that burning-lenses and the puppet-play or marionettes were derived by the Indians from the west: and there is no doubt in the minds of all unbiased students that India, especially as to mechanical inventions, owes a large debt, not to the Greeks, but to Alexandrine-Oriental-Hellenistic civilization of western Asia. I also hope to continue my studies in this direction and to furnish exact evidence for the dependence of Indian alchemy. The Indians, in my estimation, cannot be characterized as an inventive nation. There are many points, particularly as to the evaluation of Indian authors, their works and their dates, in which I am at odds with Mr. Sarkar, but discussions of this nature would require many pages and interest only the Orientalistik. Taken as a whole, his book is a valuable summary and worth reading.

B. LAUFER

APPENDIX P
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APPENDIX Q

CITATIONS & QUOTATIONS

CK Raju, *20, 34, 40, 49, 51, 54, 170, 332, 570*
B Narahari Achar*,193-197, 233, 295*
O Neugebauer*, 31, 32, 33, 34, 65, 290, 320, 321, 322, 340, 379, 573, 577, 579, 590*
D Pingree *47, 48, 49, 52, 63, 166, 210, 317, 318, 319, 324, 332, 336, 376, 561, 568, 570, 581*
R. Fitzpatrick, 283-286
Bennet, J, *et al The Cosmic Perspective, Pearson Addison Wesley, San Francisco, 2003, illustrations used in the following pages, 66, 67, 74, 87, 95, 102, 110,*
Nicholas Shanks/Glen Smith, *http://web.nickshanks.com/history/sixthousandyears, 134, 135*
Goitizolo, Miguel, *http://miguelgoitizolo.ws/TheHinduCycles.htm,* ***160****, 161*
Satya Prakash Saraswat, *133, 136, 137, 138*
Danilo Pivato*, Figure 17, Appendix A, 478*
Arun Upadhyaya*,203-204*
Bernard Laufer, *620,621*

Kosla Vepa

This book is not about the glories of a bygone era, where one bemoans the ephemeral nature of an enlightened past. It is a recounting of the irreversible nature of the changes that take place when a civilization is subjugated. Its traditions are ridiculed. Its history is rewritten, its language is driven into oblivion, and any attempt to combat this assault albeit in a non-violent and scholarly manner marks the individual as a fundamentalist. The calendar, astronomy, and the story of time combine to make a fascinating chapter in the story of the Homo sapiens, 17.

If there is one thing above all that I treasure from this experience is that the love of science and mathematics does not recognize man made geographies, boundaries, ethnic classifications, language, social strata, or economics, 17.

To what purpose, by naming an age or era as an Enlightenment era, when the elite of this era do not show the slightest signs of such an enlightenment, 37.

Incidentally, while Sir William (Jones) went on to say how much he loved Krishen and Arjun, the protagonists of the Mahābhārata War, that didn't stop him from barring Indics from becoming members of the Asiatic Society which was founded by him, 43.

The story of how the Vatican in particular and almost the entire intellectual elite in Europe collaborated over several centuries to deny the civilizations in the rest of the world their contributions to the epistemic progress in knowledge, is indeed a sordid one. This pattern of behavior is peculiar to the Catholic Church and has been practiced assiduously over several centuries. It has been institutionalized under the Law of Christian discovery, 312.



Kosla Vepa is a member of the Global Indic Diaspora, originally a native of Andhra Pradesh state in India and has had the good fortune to have been brought up and have had his education in various parts of India including, Bihar, Maharashtra, and Karnataka. He matriculated from Andhra University in 1955. Among the schools which he has attended are St.Xaviers College, Bombay, Karnatak University, Indian Institute of Science, Bangalore, and the University of Waterloo, Ontario, Canada. His highest degree is a PhD in the area of Engineering Mechanics. His professional and technical interests include successful research and development engineering experience in the Information technology, aero-engine and energy industries across the globe and an abiding interest in the history of the Mathematical sciences in antiquity. About a decade ago Dr. Vepa, decided he would like to spend more time in the area where he has a passionate interest especially in Civilizational studies in a wide variety of subjects including ontological principles in science and philosophy, Ancient Indian history, Vedas and Vedanta, Mathematical Sciences in India during antiquity, Epistemology, the growth and evolution of civilizations, Geopolitics of the Indian subcontinent, to name a few. His major activity is to further the aims and objectives of the Indic Studies Foundation, stated in the link below and to further the progress towards an accurate rendering of the narrative of the Story of the Civilization of the Indic peoples. When he finds time he pursues his hobbies of photography and astronomy, Dr. Vepa resides in the San Francisco Bay area. He is keen on developing pedagogical materials for schools in India, which illustrate the rich traditions of India in Astronomy and Mathematics.